10

3/6

DEATHS FROM TUBERCULOSIS

THE

PRINCIPLES OF HYGIENE

AS APPLIED TO

TROPICAL AND SUB-TROPICAL CLIMATES

And the Principles of Personal Hygiene in them as applied to Europeans

By W. J. R. SIMPSON, M.D., F.R.C.P., D.P.H.

Formerly Health Officer of Calcutta
Lecturer on Tropical Hygiene at the London School of Tropical Medicine
Professor of Hygiene, King's College, London
Lecturer in Hygiene, London School of Medicine for Women
Member of the Government Commission to enquire into Dysentery and Enteric in South Africa
Commissioner appointed by the Colonial Office to Investigate the Plague in Hong Kong; the Sanitation of Singapore, &c.

London

JOHN BALE, SONS & DANIELSSON, Ltd.

OXFORD HOUSE

83-91, GREAT TITCHFIELD STREET, OXFORD STREET, W.

—

1908

TO

SIR PATRICK MANSON, K.C.M.G.

WHO HAS DONE SO MUCH
FOR TROPICAL MEDICINE AND
THE PREVENTION OF TROPICAL DISEASES.

PREFACE.

TWO reasons have induced me to publish my lectures on Hygiene and Public Health in an extended form. One is that I have been frequently asked to do so, and the other is that a greater interest in hygiene and sanitation is being manifested in the Tropics, than ever was the case before. There is the same spirit abroad in tropical regions in relation to sanitary matters as existed in the early Victorian era in England, and it is likely that a book of this kind will be useful to medical men and officials interested in guiding and controlling the movement. There are many branches of the subject omitted or dealt with inadequately, but it was thought best to avoid delay, and not at present to issue a bulky volume.

The hygiene of the Tropics and of warm climates is the same in principle as the hygiene of colder climates, but the differences of temperature, food, mode of life, environment, and civilization to be found in the Tropics modify to a considerable extent the conditions under which those principles have to be applied; consequently the practice of hygiene in the Tropics differs in many respects from that pursued in colder climates, and that which is suitable to the latter is not always suitable to the former.

Whilst the general principles of hygiene remain everywhere the same, the methods by which they are put into practice have to be adapted to particular circumstances. Non-recognition of the need of adaptation of the practice of hygiene to the varying conditions met with, accounts for the frequent failures in the application of its principles. For instance, because water-sealed traps, properly ventilated, are excellent and successful appliances in English towns to keep gas from the sewers gaining access to the

dwelling house, it by no means follows that they are equally useful for the Tropics, where such traps are almost certain to be unsealed by evaporation in summer, and by pressure through storms in the rainy season. Similarly English types of latrines are seldom adapted to the habits of the people to be dealt with. Further, the muddy waters of the rivers in the Tropics frequently require a modification in the procedure of purification of that adopted with the generally less turbid waters of the temperate zone. The food differs in many respects, and is subject to deterioration and pollution of a special kind, and thus requires particular care in its storage and preparation. Insect life also, owing to its abundance and variety in the Tropics, plays a more important rôle in the dissemination of disease than it does in colder climates. And so, for these and other reasons, it happens that the prevention of disease and general sanitation in the Tropics, while following much on the lines adopted in temperate climates and European countries, also embraces measures of hygiene peculiar to hot and warm climates.

I am much indebted to Professor Hewlett for correcting the proofs for me during my absence on the Gold Coast, also to Dr. Daniels for much material assistance; and my thanks are due to Mr. C. C. James, M.Inst. C.E., for permitting me to reproduce some of the diagrams from his drainage problems of the East; also to Messrs. Burn and Co., Calcutta; to Mr. W. B. McCabe, Engineer to the Calcutta Corporation; and to Dr. Nield Cook, Health Officer of Calcutta; to Mr. Osbert Chadwick, C.I.E.; to Mr. Ault, M.Inst. C.E.; and to Mr. Shone, for valuable diagrams. I have also to thank Dr. Sandwith for some photographs of Egyptian customs.

It is through these gentlemen and others that I have been able to obtain illustrations for the book; and it is to the pleasant co-operation of the publishers that so many have been reproduced.

W. J. SIMPSON.

CONTENTS.

PAGE

CHAPTER I.

Warm Climates and *Personal* Hygiene therein 1

CHAPTER II.

Water Supply. Rain and Underground Water 23

CHAPTER III.

Water Supplies. Surface Waters 48

CHAPTER IV.

Purification of Water. Chemical Methods. Filtration Methods 70

CHAPTER V.

Examination of Water 100

CHAPTER VI.

Food Supply. The Principles of Diet and the Construction of Dietaries 109

CHAPTER VII.

Food in relation to Health and Disease 132

CHAPTER VIII.

Examination of Milk and Ghee. Detection of the ordinary Preservatives in Foods 180

CHAPTER IX.

PAGE

Conservancy or Collection. Removal and Disposal of Waste Matters. Dry System Collection and Latrines. Removal of Excreta, solid and liquid, by Manual Labour. The Removal and Disposal of Sewage. Disposal of the Excreta by Trenching 195

CHAPTER X.

Removal and Disposal of Sewage by Water Carriage System 248

CHAPTER XI.

Soil and Drainage 282

CHAPTER XII.

Hygiene in relation to Streets, Houses, &c. 294

CHAPTER XIII.

Sanitation of Jails 335

CHAPTER XIV.

Communicable Diseases 339

CHAPTER XV.

Village and Town Sanitation in relation to Malaria and other Diseases caused by the Mosquito 367

Summary of Preventive Measures employed in some of the more Common Infective Diseases prevalent in the Tropics 377

INDEX 387

LIST OF ILLUSTRATIONS.

FIG.		PAGE
	FRONTISPIECE. Coloured Plate. Deaths from Tuberculosis.	
	Chart showing Temperature of Europeans in Temperate Climates and in India, and of Natives of India ...	12
1	Covered Well in Seven Sisters without parapet and liable to contamination	36
2	Well with bath and washhouse on one side	38
	Illustrations showing condition of compound of a hut inhabited by twenty-six persons and in which three died of cholera	38-39
3	Water-boring Operations on a farm in South Africa ...	40
4	Plan of Protected Well suggested by Sir William Macgregor	43
5	View of Tolly's Nullah, crowded with boats carrying pilgrims and with pilgrims bathing in the sacred stream	61
6	Underground Porous Water Tank, showing liability to contamination	62
7	Water Carrier emptying his mashak into household water vessel	65
8	Water being carried from the river	66
9	Lagoon and Rushes, Mare aux Vacoas, Mauritius ...	73
10	The Overflow, Mare aux Vacoas, Mauritius	74
11	The Anderson Apparatus, Mare aux Vacoas, Mauritius	74
12	Details of Aerating Plant, Mare aux Vacoas Water Works, Mauritius (*folding*)	76
13	The Ozonizer of the Siemens-Halske Apparatus ...	77
14	Diagrammatic Plan of the Siemens-Halske Plant for the Sterilization of Water by means of Ozone ...	79
15	Portable Apparatus for Use in the Field for Sterilization of Water by Ozone (Siemens-Halske system) ...	80

FIG.	PAGE
16—Apparatus for Sterilization of Water by Heat	86
17—Sketch of Maiche "Sterilizer"	88
18—Diagram of a Section of a Sand Filter	93
19—Diagram of a Mechanical Filter	96
20—A Milk-seller's Yard	153
21—Photograph of a Milk-seller's Premises and Cow-shed ...	154
22—Measly Beef; Cysticercus of *Tænia saginata* embedded in the muscle	165
23—Measly Pork; Cysticercus of *Tænia solium* embedded in the muscle	165
24—*Cysticercus bovis*, with evaginated head	165
25—Head of Cysticercus of *Tænia saginata*, with suckers and vascular ring	166
26—*Cysticercus cellulosæ*, the common bladder-worm of the pig	166
27—Cephalic end of *Tænia saginata;* Egg of *Tænia saginata* containing the embryo; Mature Segment of *Tænia saginata*	168
28—Head of *Tænia solium;* Two Proglottides of *Tænia solium* with branched uterus ; Eggs of *Tænia solium*	169
29—Apical Surface and Circle of Hooks of *Tænia solium* ...	170
30—Free swimming Embryo of *Dibothriocephalus latus;* Eggs of *Dibothriocephalus latus;* Larvæ of *Dibothriocephalus latus;* Head of *Dibothriocephalus latus*	178
31—Chinaman watering vegetables with sewage	179
32—Plan of Latrine, showing half-section and elevation and end view (*folding*)	202
33—Plan of Latrine, showing sections and roofing (*folding*)	202
34—The Horbury pattern of Public Latrine	205
35—A double Public Latrine	205
36, 37, 38—Anti-splash Pails	204
39—Upper-story Privy in Bombay	206
40—Upper-story Privy, showing pipes to carry off soil water, receptacle in privy vault, Mehtranee	208
41—Latrine used in Hong Kong, with plan and longitudinal section (*text and folding*)	210
42, 43—Plan and Elevation of simple Oriental Latrines	212, 213
44—Plan of Latrine for private house	214
45—Double Latrine, with glazed stoneware platforms ...	215
46—Public Latrine, with six seats	216

FIG. PAGE
47—Patent Foot-rest Dry Pan Closet 217
48—Various types of Soil Pans in use 218
49—Various methods of arranging compartments of Latrines 220
50—Night-soil Bucket used in Calcutta 223
51—Calcutta Night-soil Cart 224
52—Calcutta Night-soil Cart, plan and side elevation ... 225
53—Crowley's Night-soil Cart 226
54—Night-soil Cart, cylindrical pattern 226
55—Night-soil Cart, with discharge valve opening underneath 227
56—Tonne Vidangeuse Pneumatique Automatique 228
57—Calcutta Night-soil Depôt, with reservoir (*folding*) ... 236
58—Plan of Septic Tank Latrine (*folding*) 236
59—Washing Day 241
60—House with Latrines arranged in separate tower approached by verandahs 250
61—Connected Latrine in Calcutta 252
62—Intermediate Privy adapted to high houses and sewerage system of Bombay 254
63—A connected House Latrine, Calcutta... 256
64—House Latrines arranged by Mr. Ault for Rangoon ... 257
65—Public Latrine and Urinal, Calcutta (*folding*)... ... 258
66—The Shone System 260
67—The Shone System ; plan of Manhole and Ejectors ... 261
68—The Shone System ; Method of Ventilation (*folding*) ... 264
69—Diagram of Distribution of Sewage on a Sewage Farm by the catchwater system and bed system ... 267
70—Sewage Farm, showing arrangement of ridges and furrows 268
71—Scott-Moncrieff System, as arranged by Major Roberts 275
72—Same, but on account of gradient sewage raised by Persian Wheel 276
73—Covered Hydrolytic Tank 278
74—Water-supply without provision of drainage 285
75—Intercepting Channel to cut off Underground Water ... 288
76, 77, 78, 79, 80—Plans A, B, C, D, E, to illustrate Insanitary Areas at different stages ... 294, 296, 298, 299, 300
81—Plan showing mode of dealing with Insanitary Areas (*folding*) 300
82—Plan showing improvement effected in an Insanitary Area in Macao 302

FIG. PAGE
83—House fronting the street, with another house built in the rear 306
84—Types of badly-designed Houses 309
85, 86, 87, 88, 89—Five Plans of Houses, showing sections, &c. (*folding*) 310
90—Plan showing arrangement of Huts with roadways ... 315
91, 92, 93—Insanitary Huts 316, 317
94—Row of improved Sanitary Huts 317
95—Cow-shed 319
96—End view of Calcutta Jail Dormitory 329
97—Plan of Jail Latrine 331
98—Donaldson Destructor 336

ERRATA.

Page 9, last line, for "1885" read 1865.
Page 47, line 3 from top, for "loam" read chalk.
Page 50, line 10 from top, for "Blysca" read Blyxia.
Page 91, line 16 from bottom, for "4 mm." read ·4 mm.
Page 112, line 10 from bottom, for "lájra" read bájra.
Page 148, line 3 from bottom, for "egotized" read ergotized.
Page 157, line 15 from bottom, for "serious" read serous.
Page 188, line 12 from bottom, for "dobi" read dohi.
Page 189, line 11 from top, for "gowalters" read gowallas.
Page 190, table, line 4 from top, for "Wollney" read Wollny.
Page 262, line 12 from bottom, for "B" read D.
Page 270, line 16 from bottom, for "Descat's" read Ducat's.
Page 362, line 17 from top, for "Threshes'" read Thresh's.

TROPICAL AND SUB-TROPICAL CLIMATES

And the Principles of Personal Hygiene in them as applied to Europeans.

CHAPTER I.

WARM CLIMATES AND *PERSONAL* HYGIENE THEREIN.

Extent of Tropical and Sub-Tropical Zones.—The region of warm climates, as distinguished from temperate and cold, extends some 35° north and south of the Equator, and includes the tropical and sub-tropical zones. The torrid zone, which is within the Tropics and which has the highest mean annual temperature, comprises that belt which lies between the north and south parallels of 23° 28′ 40″. The northern parallel is the Tropic of Cancer, the southern the Tropic of Capricorn. Between these parellels is the ecliptic, or apparent path of the sun, and accordingly over some part of this belt the sun is always vertical. In its apparent passage the sun travels between these parallels at an unequal pace, which is more rapid near the Equator than at the Tropics, and hence the duration of the vertical position in different parts of the belt varies. This variation has an important bearing on the temperature, for, other things being equal, the longer any portion of the earth is exposed to the vertical rays of the sun the hotter it is. As the sun remains longest vertical or nearly so in the Tropics of Cancer and Capricorn, these regions attain the highest temperature.

The sub-tropical zone is a region extending beyond the belt of the zodiac to 35° latitude north and south, and comes under the powerful influence of the sun on its approach to the Tropic of Cancer or the Tropic of Capricorn. The climate of this vast region, embracing some 70° of the earth's surface, varies greatly, depending on a number of conditions which either singly or collectively exercise a modifying influence. Humidity of the air, rainfall, soil, latitude, vegetation, proximity to the sea or to large tracts of water, and exposure to or direction of the winds are important factors.

Zones of Climate do not correspond with Zones of Latitude.—Zones of climate are accordingly not coterminal with zones of latitude. This is evidenced by the irregularity of lines and curves which are displayed on the charts of the world showing the annual isothermal lines or lines of equal temperature in different places. The area in which the mean annual temperature of 80° F. occurs is very irregular in its outline ; in some parts it narrows down to near the Equator, in other parts it widens out to the extent of passing beyond the Tropic of Capricorn and Tropic of Cancer. On one side it extends from Africa well into the Pacific Ocean, and on the other to a large portion of Southern and Central America. Within this area of greatest continuous heat are to be found certain localised centres in Central America, in Central Africa, in Central India, and in Northern Australia, whose annual mean is considerably higher than 80° F.

The irregularity of the isothermal curves is even more marked in the isothermal charts of January and July than in those of the mean of the year.

Regularity of Isotherms, and their running parallel with the Degrees of Latitude, could only occur if there were Uniformity in the Earth's Surface.—Regularity of the isotherms and their running parallel with the degrees of latitude could only occur if the earth's surface were uniform instead of presenting, as it does, every variety of irregular distribution of land and water, mountain

and valley, barren soil and fertile plain, all with different powers of absorption and radiation of heat, and exposure to the influence of currents of water and winds. In consequence of these varying physical features, as well as of the position of the sun, places with the same mean temperature do not always possess the same climates. Islands compared with continents possess different kinds of climates, though their mean temperature may be the same. The climate of the islands of the tropical seas is very different from that of North or South Africa or Northern India. There is often not more than 2° or 3° F. between mean temperature of the hottest and coldest month of the year in the islands of the equatorial regions, while in the drier sub-tropical regions there may be a difference of 50° F. or more. Over the coasts and the islands of tropical seas daily land and sea breezes serve to temper the heat, and tend to lessen the extent of the diurnal and annual ranges of temperature. These breezes are caused by the different degrees of rapidity with which land and water absorb and part with the radiant heat of the sun. Land is more easily heated than water and gives off its heat more readily.

The surface temperature of the ground may rise in a hot country to nearly 200° F. or over, while the surface temperature of water rarely reaches 90° F. During the day, when the sun's rays are powerful, the air in contact with the land is heated, expands and ascends more rapidly than that over the sea, and towards the latter part of the day a sea breeze sets in, blowing from the sea on to the land, bringing the cooler air which has been in contact with the sea to take the place of the heated air on land. During the night the process is reversed; the land radiates its heat more rapidly than the water does, and in consequence the air in contact with the land becomes cooler than that over the sea, so that in the early morning a land breeze—that is, a breeze from the land to the sea—begins to blow. From the same causes the presence of large sheets of water or

lakes inland has an important balancing effect on the temperature of the air in its vicinity.

In tropical and sub-tropical continents this modifying influence of the sea is absent. The effect of solar and terrestrial radiation on the atmosphere is more marked, and the diurnal and annual ranges of temperature are greater. The kind of soil in a locality has an important influence on the temperature of the air, for soils vary much in their relative power of absorption and also in their power of radiation, and this is influenced again by the soil being covered or not by vegetation. Soils covered by vegetation are always cooler than those that are bare. Generally the soils most absorbent of heat are those which radiate it most rapidly. Sandy soils with lime are the hottest, and give rise to the highest air temperatures. The glare from such soils, and the hot particles of dust lifted into the air by the winds are very trying. Humus or mould is the least heat-absorbent soil, having a capacity in this respect of about half that of sand. Clay soils are intermediate in position between sand and humus, and are generally, in the Tropics, on account of their retentiveness of water, the coolest.

Effect of Humidity.—Humidity has a powerful effect in modifying and regulating the heat. When the relative aërial humidity is great it remains like a blanket over the land, preventing rapid evaporation and radiation, and hence the variations in temperature are small, and the climate is equable; on the other hand, when the relative humidity is low and the atmosphere is dry, evaporation and radiation proceed rapidly, the soils most absorbent of heat during the day cool rapidly at night, and the climate is subject to great diurnal fluctuations.

It is because of the abundance of rain and the amount of watery vapour in the equatorial regions that the temperature, though high all the year round, never reaches those extremes which are found further away from the Equator and in drier regions.

Distribution of Rain Important in the Formation of Climates.—The distribution of rain, therefore, is an important factor in the formation of climates. In warm regions the heaviest rainfalls are on the islands on or near the Equator, certain coast-lines in the equatorial and tropical regions, and a few highlands within the Tropics; the lightest rainfalls are on the plateaux and inland regions lying on the leeside of mountain ranges; and there is the vast rainless tract, which forms a more or less continuous belt of desert, separating the torrid zone from the temperate zone.

From the distribution of rain and the distance of the locality from the Equator, a fair conception may be formed of the general character of the climate and seasons, although it must be borne in mind that local conditions, such as soil, elevation, exposure to winds, and maritime or inland positions, effect important changes and cause variations. Generally it may be stated that where rain and moisture are abundant the climate is not excessively hot, but steamy, damp and oppressive, and the range of temperature is limited. Where the rainfall is scanty the climate is intensely hot and dry in summer, and the range of temperature is large. Between these is every variety approximating more or less to one or the other. The parts of the earth which attain the greatest heat are in or near the Tropics, and they are the driest regions.

Character of Rain Within the Tropics.—Rain within the torrid zone is usually a much more decided affair than elsewhere. There are seldom any drizzling rains such as are to be met with in England and Scotland, but the showers, however short or long in duration they may be, are heavy. It is this feature of the rainfall which, unless the ground is very porous or has natural advantages in slope, favours floods, inundations, and the formation of swamps, which require special contrivances and drainage for their prevention. The rain, besides coming down in heavy showers, falls, except on the

Equator, more periodically and regularly than in other parts of the world. On the Equator it may fall at any time. A cloudless sky and no rain for a few days or weeks bring intense heat in these regions. From 5° to 10° from the Equator, rain falls when the sun is in the zenith and approaching the Tropics, and again on its return towards the Equator, so that there are two rainy seasons. In those regions further away from the Equator there is only one rainy season during the year. In Ceylon, for example, the rainy season is in May and June with the south-west monsoon, and again in October and November with the north-east monsoon. Rain, however, falls in every month. In India the rainy season is chiefly regulated by the monsoons, which is the name given to the predominant winds. From October to March the north-east monsoon prevails; it is a cool and dry wind, having passed over vast tracts of land. From April to October the south-west wind predominates. It is a hot wind, charged with moisture from the southern seas, and for three or four months in the year brings rain to the greater part of India. When the sun is vertical in the northern hemisphere, there is a gradual heating up of the land until it becomes like a fiery furnace. With this intense heat the barometric pressure is gradually lowered, and air currents from the southern seas rush into the vacuum, preserving in the main a south-west direction. Laden with moisture, this south-west monsoon, when it strikes on high land, as on the Western Ghauts, on the Malabar coast, on the mountains of Tenasserim, and on the mountains of the Himalayas, where it meets with colder air, deposits its moisture in the form of heavy rain, reaching as much as 121 in. at Cannemore (Malabar), 253 in. at Mahableshwar, 180 in. at Moulmein (Tenasserim), and 600 in. at Cherrapunji (Khasyah Hills).

Having lost much of its moisture in its passage over these highlands, the inland districts may be comparatively dry. Or even in places near the sea, where there are no highlands, the rainfall may be small, as at Karrachi.

Climate and Vegetation. — Climate expresses itself so strongly on the vegetation in the Tropics that it is easy from the vegetation to form an opinion of the kind of climate possessed by the locality. Where the vegetation displays an endless variety of plant life unknown to Europe, decked in gorgeous colours and reproducing itself in the most luxuriant growths, the climate is sure to be hot and moist. It betokens perennial warmth, great moisture, and equable seasons. It is under these conditions that Nature is prodigal of her richest productions, and it is with difficulty that vegetation can be kept within limits. If a locality or village be deserted for a time, such is the rapidity with which grass, creeper, and jungle grow, that the site will soon be hidden. Where the vegetation is less luxuriant, but of the same tropical nature, the climate will be hot but with plenty of rain, and in those regions where the heat is strong but the rain fails the vegetation fails also, and the land approaches the appearance of a desert.

Rapid Putrefaction and Fermentation.—The luxuriance in plant life in the Tropics extends also to the lower forms of vegetable life. Putrefaction and fermentation proceed with more rapidity in warm climates than in others, and especially is this the case in hot and humid climates. It is under these conditions that the microscopic agents which Nature uses in her laboratory can work best in disintegrating dead matter, and convert the organic into the inorganic. But during the process, and until the work is complete, there is the possibility of compounds being formed or the agents themselves acquiring properties hostile and dangerous to man. Similar processes go on in cold climates, but not with the same energy or rapidity of development. That which proves to be hurtful in Europe is doubly so in the regions we are dealing with. The same meteorological factors favour the development of germs and parasites which give rise to diseases almost peculiar to the climates.

Geographical Distribution of Parasites and Correspond-

ing Geographical Distribution of Disease.—There is a climatic or geographical distribution of parasites, and with this a corresponding geographical distribution of disease. For instance, there are endemic areas for yellow fever in South America, the West Indies, and on the West coast of Africa; for cholera in the Delta of the Ganges; for beri-beri in Brazil, Malayan Archipelago, China and Japan; for plague in Arabia, Mesopotamia, Ghurwal and Kumaon in India, Yunnan in Western China, and Uganda in East Africa; for sleeping sickness in British East Africa; for Malta fever on the Mediterranean coast; for filariasis in South America, West and East Africa, India and China; for guinea-worm, *Bilharzia hæmatobia*, and dysentery in nearly every part of the Tropics. The germs or parasites of these diseases thrive best in their endemic or home areas, finding in them congenial conditions for their development, just as plants and different races of men thrive best in their original homes. Both may occasionally swarm over the boundaries of their natural home, but they encounter difficulties in becoming acclimatised, and in reproducing themselves and thriving in their pristine vigour in regions widely different from that in which they were nurtured, and in the struggle they usually lose their qualities, or die, or become absorbed into the type. The endemic homes of disease are of the highest interest from an epidemiological point of view, for it has still to be determined why the germs and parasites peculiar to these endemic areas, and productive of disease in a sporadic form, should not thrive except occasionally in other regions where apparently similar conditions exist. A remarkable instance is that of yellow fever, the prevalence of which is attributed to the rôle which *Stegomyia fasciata* plays as a carrier of the infection, and the very limited endemic area of the disease, notwithstanding the wide distribution of the mosquito in question.

Effect of Insanitary Conditions Attributed to Climate.—It will be seen, therefore, that immediately a European

enters the Tropics he comes under the influence of a new environment which is destined to impress itself on him, though not in the manner that was understood in the early part of the century, when every illness which occurred in warm climates was attributed to climatic causes, instead of—as in the majority of cases—to the most flagrant breach of sanitary laws. This was particularly the case in the West Indies, where the mortality amongst European soldiers was the highest recorded anywhere. Fever, scorbutic dysentery, and phthisis were extraordinarily prevalent, and it was estimated that the lifetime of a regiment 1,000 strong was about five years. This mortality occurred under the following conditions: The food of the soldiers consisted mainly of salted meat, with but a scanty supply of fresh vegetables; the drinking water was taken from polluted sources; the barracks, built on unhealthy sites, were badly constructed, without ventilation, and were overcrowded, the cubic space for each man being about 250 feet; the sanitary arrangements were foul and neglected, and of the most primitive character. Add to these over-eating, intemperance in drink, unsuitable clothing and no exercise, and there is a ready explanation of the great mortality without blaming the climate. The mortality in the twenty years from 1817 to 1836 was in Jamaica 121 per 1,000, in Trinidad 106, in Barbados 55, in St. Lucia 122. When the conditions mentioned were improved a steady decline took place in the death-rate, which has fallen more than ten times. Scorbutic dysentery has disappeared with the introduction of fresh meat and vegetables and pure water; phthisis has been greatly reduced by better ventilation and less crowding of the barracks; and the general mortality is not more than that in England among the troops stationed there.

A similar change has taken place in the European troops in India. In the early part of our occupation the death-rate was 80 per 1,000 among the troops; even as late as 1885 it was 69 per 1,000. This has been

altered, and, by the introduction of sanitary measures and attention to the diet, drink, clothing and exercise of the soldier, the death-rate is now less than 16 per 1,000.

The same decrease in mortality has happened in the European civil population with a better understanding of the mode of life to be followed in the Tropics. In Calcutta, for instance, in the early days, the principal inhabitants used to meet under a tree on the Maidan and congratulate one another that they had escaped alive through the rains. Now, for Europeans Calcutta is in many respects as healthy to reside in as towns at home.

The West Coast of Africa was also in the early part of the century the white man's grave, the mortality from 1817 to 1837 in Sierra Leone being 170 per 1,000. Earlier it was 480 per 1,000, the greater portion of which was due to dysentery. In the 'sixties this rate came down to 80 per 1,000, and it has declined still further; and though the towns on the West Coast of Africa have still a most excessive death-rate, there can be little doubt that, by the systematic adoption of the same hygienic measures as those that have proved so successful in the West Indies and in India, the mortality will decline.

The Apportionment of Ill-health due to Climate and to Insanitary Causes Difficult.—Under the conditions of bad hygiene, personal and general, unsuitable food and excessive drinking, it is difficult to adjudge the proportion of ill-health due to climate and to preventable causes; but when experience shows that by the removal of insanitary conditions and placing the individual under favourable hygiene, in relation to surroundings, housing, diet and clothing, the mortality which used to be ascribed to climate can be reduced ten to fifteen times its former rate in the West Indies, and at least five times its former rate in India, the question arises whether, apart from inattention to personal hygiene, insanitary conditions and

malaria, residence in the Tropics is more unhealthy to a European adult than residence in his own country. Whatever answer may be given to this question, it is certain that in the vast majority of cases residence for a short time in the Tropics is not productive of any ill effect to the constitution. Prolonged residence without change, on the other hand, is seldom without its dangers. There can be no doubt that a high temperature combined with much moisture, which characterises many of the climates in the Tropics, is debilitating to Europeans, and necessitates, as a rule, frequent visits to cooler climates. For this reason, sanatoria or hill stations should always be established in tropical regions whenever possible, in order that the women and children, during the most trying part of the year, may be able to live in a moderately cool climate and not be subjected to the exhausting conditions of the plains, and in order that the men may have an easily accessible health resort to recruit in when occasion requires it.

Prolonged exposure to intense heat, whether dry or moist, has, as a rule, a debilitating effect, but of the two the dry heat can be endured with greater comfort, and it is the more healthy and the less debilitating.

Physiological Effects of Tropical Regions on the European.—The new environment produces a certain change in the individual inducing a susceptibility to diseases or disorders peculiar to the Tropics. The climate, the general character of the plants, the inhabitants, their food, clothing, habits, customs, mode of thought, and their diseases, differ widely from those which are usually to be found in a temperate zone. They are factors which are bound to gradually affect the new-comer, and they necessitate a certain adjustment to the new conditions on the part of the individual. This adjustment, in some respects, may be voluntary, but in others it is involuntary and beyond control.

For instance, as regards involuntary adjustment, the effect of a tropical climate, whether dry or moist, on

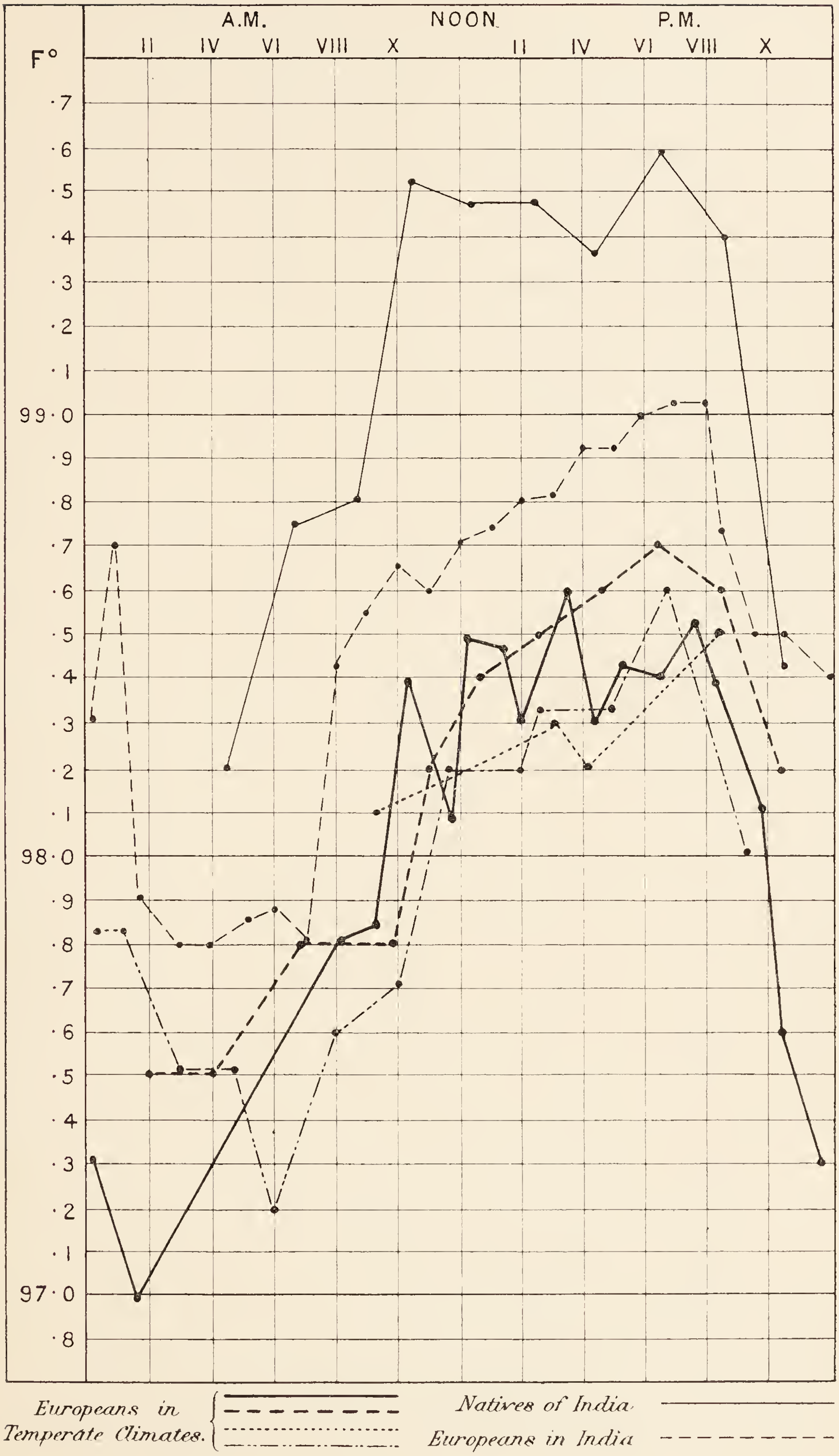
a European constitution, is to gradually bring about a change in the customary physiological functions of certain organs of the body. The change is an effort on the part of the system to adapt itself to the new conditions. Until this process of acclimatization is fully attained and the system has accommodated itself to its surroundings, the individual is, from the slightest indiscretion, highly susceptible to disorder and disease. The most important of these changes are a greater supply of blood to the surface of the body and a greater activity of the functions of the skin, which, by profuse perspiration, keeps the body at its ordinary temperature. Persons who do not perspire, or who suffer from some defect in their sudorific system, are accordingly not adapted to the new conditions to which a hot climate subjects them, and should not go to the Tropics. The adjustment of the system to counterbalance the additional external heat is not completed for some time in the newly-arrived European, and until that time is reached the temperature of the European is slightly higher than normal. It is stated that the temperature of the body rises 0·05° F. for every 1° F. increase in the temperature of the air. Numerous experiments have been made by several observers which corroborate this statement. Dr. Crombie has shown that the body temperature of Europeans living in Bengal is about 0·41° higher than the average of healthy persons in England. This is shown by the following table :—

TEMPERATURE IN EUROPEANS IN TEMPERATE AND WARM CLIMATES.

	Mean A.M.	Mean P.M.	Mean	Mean daily
English average	97·963 ...	98·341 ...	98·084 ...	1·41
Crombie's Indian average for Europeans (1,268 observations)	98·21 ...	98·77 ...	98·49 ...	1·31

The chart shows in a graphic form the results of observations on temperature among Europeans in temperate climates, and Europeans and Natives in India. When

BODY TEMPERATURES.



Face p. 12.

the temperature observations are charted and compared, it is to be noted that the European in India has a higher temperature than the European in a temperate climate, and that the Native of India has a higher temperature than the European in India.

Exercise Raises the Temperature.—It is important to remember that exercise in the Tropics raises the temperature, and that if the temperature is recorded in the afternoon, when exercise is usually taken by the European, the temperature will be found to be higher than at other times of the day. A long march in the sun, especially if the dress is unsuitable and clothing tight, is apt to produce a considerable rise in temperature, which otherwise might be considered to be due to malaria. These fevers due to fatigue and exposure to the sun are ephemeral in their nature, and the patient is usually well in a few days. They are not to be mistaken for the fevers dependent on more specific causes. The temperature of the body in the Tropics is more easily disturbed by the temperature of the air, by food, or by exercise, than it is in cold climates.

Other important changes take place in the bodily functions when an individual is transferred to a tropical climate. Owing to the new distribution of blood and its diversion to the surface of the body, the capacity of the lungs increases. It has been estimated that as much as 23 ounces of blood have been withdrawn from the lungs under the influence of a temperature of 80° to 83° F. The space occupied by the blood is replaced by air, hence the lungs weigh less in hot than in cold climates. Notwithstanding this change, which gives increased capacity to the lungs, they perform less work in warm climates, because at the same time the number of respirations is reduced. This reduction in the number of respirations, combined with the fact that the air, rarefied by heat, contains less oxygen than the same quantity of cold air, effects an important change in the physiological working of the lungs. Less oxygen is inspired,

and about 20 per cent. less CO_2 and watery vapour are given off by the lungs. It is estimated that 9 per cent. less oxygen is inspired at 80° F. than at 32° F. Changes of this kind tend to produce a retention of carbonaceous matter in the blood. With these changes there is a greater functional activity of the skin, liver, bowels and spleen. Generally, however, the effect of a warm climate is to diminish the vital activities; thus the pulse is slowed and the heart's action weakened, the powers of digestion are enfeebled, the appetite is lessened, nutrition depressed, manifesting itself in loss of weight or a superfluous deposition of fat and lessened bodily vigour. The nervous system, which is first of all stimulated and later depressed, is put in a state of tension which allows it to be easily affected by external impressions. This process of acclimatization, or accommodation of the system to the new conditions and to the change in the activity of the physiological functions of the skin and other organs, is estimated to take about four years. It is during this period that disorders are most liable to occur, but with care, and provided the organs are in a healthy state when the European enters the Tropics, these changes consort with a feeling of health, and it is only after a prolonged stay in the Tropics, or when the individual has some weak point in his constitution, or is the subject of syphilis, or indulges too much in alcoholic drinks or in smoking, or, most frequently of all, when the laws of health are not attended to, that the relaxed state of the system is followed by derangement and disease. Two results are noted among those who have spent many years in the plains of tropical regions, even when they have never suffered from malaria; one is a pallid condition, and the other is a loss of muscular strength, with a corresponding inability to undergo much fatigue. Acclimatization of pure Europeans, in the sense of acquired power of permanent residence in the Tropics for several generations, does not take place.

Pathological Effects of Hot Climates; Illnesses, Nervous or Congestive.—The illnesses of the Tropics, with the

exception of those caused by parasites, microbes, and insanitary conditions, are essentially of a nervous or of a congestive character, and may fairly be attributed to climatic causes. Sleeplessness is one of the effects which a tropical climate may produce. Heat and exposure to sun, wind, and rain in the Tropics are apt in a special manner to disturb the functions of the body, causing illnesses which are characterised by high or low fever of an ephemeral nature, but may be severe in character, sunstroke being the usual form, or by well-marked derangement of some internal organ. In the *nervous class* the nervous system may lose its tone, and its firm governing power over the heat-regulating centres of the body; or it may sustain a shock from which it is unable to recover. In the *congestive class* the action of chills on a sensitive perspiring skin suddenly drives the blood from the surface of the body into the interior, and there induces disturbance of the vaso-motor system, and congestive disorders affecting the liver and bowels. The same may be the result of injudicious food and drink, clothing, exercise, bathing, or other circumstances, all or every one of which may increase the slight congestion of the abdominal organs which, owing to the relaxed condition, becomes the normal state in the Tropics.

Avoidance of Undue Exposure to Sun.—The practice in the Tropics of personal hygiene is based on the foregoing considerations. Undue exposure to a tropical sun without sufficient protection is to be avoided The heat rays of the sun are seldom felt so much by a new arrival as by older residents, and accordingly there is a tendency to pay but a modicum of that respect to the sun which experience teaches to be necessary. The effects, therefore, are apt to be injurious, and the new-comer incurs a considerable risk of suffering from nervous depression, sun fever, or perhaps, worse still, from sunstroke. New arrivals are always more liable to suffer than older residents. There are some hot climates, particularly on high plateaux, where sunstroke is unknown, and where

a headgear of special design is not worn ; an ordinary single or double Terai hat is sufficient protection. But for India, and all those tropical regions where the sun's atmospheric conditions are dangerous, exposure to the sun in the hot season demands thorough and special protection of the head, and for many persons the protection of the spine as well. In India this is effected by the solah topee, which is made of the pith of an Indian rush. It should be light, shaped to shield the temples and nape of neck, and so ventilated that the hot air covering the head shall readily escape and be replaced by fresh air. The ventilation of the topee is important for comfort and health. This is best effected by the topee not fitting to the head directly, but having inside a narrow band which encircles and fits the head, and which is attached to the topee by a few widely separated pieces of cork. This permits of a free circulation of air between the topee and the head, and is better than any openings at the top of the hat. The solah topee is light, and is superior in protecting qualities to either felt or cork, the latter of which is too heavy. The slanting rays of the sun in the morning and in the afternoon are often more dangerous than the vertical rays of midday, because of the direct exposure to them of the unprotected eyes, nape of neck or temples, which are all particularly susceptible to their powerful effect. In places where the glare is great the eyes need protecting by wearing neutral-tinted spectacles. As the spine is sensitive to the sun's rays, a spinal pad fixed temporarily in the lining of the coat is an additional protection, especially when out riding.

Orange-coloured Material to Protect against Actinic Rays of Sun.—It is held by some that it is the actinic rays of the sun which are injurious rather than the heat rays, and under this supposition the topee and the pad are lined with orange-coloured material ; and for the same reason a shirt of that colour may also be worn. Though care should be taken to avoid undue exposure, and to secure sufficient protection against the direct rays of the

sun during the five or six hottest hours in summer time, and in some localities even for longer, nevertheless as much time as possible outside of these hours should be spent in the open air. Experience has shown that ill-health arises when soldiers are confined during the day in the Tropics to close barracks, and hence every outdoor amusement is encouraged, except during a few of the hottest hours of the day. Confinement to close and darkened rooms in a great measure accounts for the exceptional ill-health which European women as a rule suffer from in the Tropics.

Exercise necessary.—Exercise, regular, and short of fatigue, is absolutely essential if health is to be retained in a warm climate. The people who enjoy the best health are those who are fond of riding and of outdoor exercise, such as lawn tennis, rackets, golf, and other similar pastimes. There is a great temptation to lead a sedentary life, but it must be resisted.

Exercise stimulates the body to get rid of its effete matter; it improves the digestion and thereby promotes assimilation; it gives vigour to the circulation through a torpid liver; it increases peristaltic action of the bowels and removes constipation; and it increases the respiratory movements, and the amount of CO_2 expired by the lungs, relieving the tissues of waste products. Harm may accrue, however, if the exercise is overdone; exhaustion ensues, the by-products of tissue-change remain in the blood, and fatigue fever is the result. Great care must also be taken after exercise, when the surface of the body is hot and the skin profusely perspiring, that no chill is caught by sitting in a draught, or under a punkah, or by exposure to a cool wind. If it is impossible at once to get a rub down and make a complete change of clothing, the next best plan is to put on a sweater or greatcoat to prevent any risk of chill. Ladies are more liable to the effects of chill than men after exercise, because of their dislike of immediately putting on warm wraps.

Effects of a Warm Bath.—A warm bath prevents chill and is refreshing. Few people can in a hot climate continue the cold bath to which they have been accustomed in England. It is apt to produce, especially when the body is over-heated or fatigued, congestion of the internal organs. A cold bath is also prone to cause disturbance of the bowels and liver, and subsequent ill-health, when taken in the hills on immediate arrival from the plains.

For those who suffer in any way from bowel complaint or from disturbance of the liver, the cold bath is unsafe at all seasons of the year, and the warm bath is absolutely essential.

For healthy Europeans the tepid bath is, as a rule, the more refreshing, though some Europeans are able to go on with their cold bath. The bath can be taken at any time except while the process of digestion in the stomach is going on.

Great care must be taken as to the source of the water for bathing purposes, and that it is clean. Unless the water is derived from a source which is beyond suspicion it should be boiled. Bathing in hot water in the Tropics has other advantages than the prevention of chill. This specially applies to regions where anchylostomiasis and bilharziosis are common. For anchylostomiasis it has been proved by Professor Loos, and for bilharziosis suspected, that one of the channels of infection is the skin, through which the larvæ in infected water or mud penetrate in order, in the case of *Anchylostomum*, to reach the duodenum, and in that of *Bilharzia* to reach the portal veins. The larvæ of *Anchylostomum* enter the skin through the hair follicles, and, when in numbers, set up a good deal of irritation. Bathing in stagnant pools should always be avoided.

Chill plays an important part in exciting Disease in the Tropics.—Dress is an important matter in warm climates, both for comfort and health. The garments next the skin should keep the body at a uniform temperature,

thereby preventing chill, for chill holds a very important position as the exciting cause of disease in warm climates. The sensitive and perspiring skin, the large amount of blood circulating near the suface of the body, and the lax condition of the vaso-motor system, are easily affected by external impressions. Anything conducive to chill, whether it be caused by rain, exposure to a cold wind, or other circumstance, is apt to act on the vaso-motor system, check perspiration, and drive the blood into the internal organs, setting up disturbances of the liver, lungs or bowels, and in the subjects of malaria inducing a recurrence of the disease. It is easier to take cold in a hot climate than in a temperate one, because in the latter care is taken to cover the body with suitable clothing. To fulfil the object in view, the clothing next the skin requires to be loose, in order that there shall be free circulation of air between it and the surface of the skin ; it requires also to be made of absorbent and porous material to prevent rapid evaporation and the production of chill. Wool and silk possess these properties in a high degree, and are more suitable for underwear than either cotton or linen. Cotton, however, when loosely woven, gains in absorbent properties, and when mixed with either wool or silk is very light and comfortable. Pure wool has certain disadvantages. If it is coarse, it is likely to irritate the skin and aggravate the symptoms of prickly heat ; and if it is closely woven, or has been washed much in hot water, it is prone to become hard and lose its absorbent and porous properties. Only the finest woollen material and loosely woven should be used, and if this cannot be worn, and silk is not found sufficiently absorbent, the best substitute is "Anglo-Indian gauze," which is a mixture of wool and silk. Another material, which, however, is not so good as the Anglo-Indian gauze, is a mixture of wool and cotton. Cellular cloth is sometimes worn with comfort, for though its fabric is of cotton it is so made as to be absorbent. A cholera belt, which is the name given to a knitted belt placed round the body below the waist, and

which is best made of Jaeger wool, should always be worn both by men and women. One should be worn during the day and another at night. It protects parts particularly susceptible to cold. In order that the cholera belt shall not shift its position, it is best to have it attached to the pyjamas and under-drawers. As long as the fundamental principle of wearing loose woollen or silken garments next the skin is practised, the kind of upper garments worn is of small moment and varies much in different places. They should be loose and light in weight. The colour should be white, grey, or khaki, as these absorb the sun's rays least. Dark colours are not advisable except in the evening, and even then white is preferable. Sleeping suits and garments should always be of fine flannel or a mixture of wool and silk. During sleep, especially in the early morning hours, the body is particularly liable to chill unless well protected by woollen garments. When camping out a Jaeger sleeping sack, or one made out of ordinary blanket, is a great comfort and is a special safeguard against chill. During the hot weather and rains the body perspires on the slightest exertion, and it is necessary to change the clothes several times a day, and especially so before sundown. Damp clothes require to be regularly dried and aired before being put on again, and in the rains they should always be dried every night.

Sleep.—A sufficiency of sleep is essential to health in the Tropics. Hot and sultry nights are prone to disturb sleep, the tendency to which is aggravated by irregular habits and hours in going to bed. Lateness of hours should be avoided, and an hour's rest during the hottest part of the tropical day should be taken if possible.

The bed should always be provided with a mosquito net having a fine mesh of at least twenty strands to the inch. Fine muslin is even more protective than mosquito netting, as it excludes sand-flies as well, but on sultry nights it is somewhat oppressive. The net should be hung from the inside of the frame which is supporting it, so that the poles may not interfere with its proper

adjustment. The curtains should also be let down and fixed well before sundown. They should be tucked under the mattress, and not let down on to the floor. In order to avoid bites from mosquitoes owing to the arms coming in contact with the curtain, it is safer to have the lower part of the mosquito curtain for a foot or more, of double calico.

Food and Drink.—Food in the Tropics is at first a difficult matter for the European. His natural craving for meat and fats inclines him to partake of too much animal food, which is by no means suitable for him with the new conditions of climate, and which, in the form of tin-preserved meats or the badly cooked fresh meats of the country, has more to do with dyspeptic conditions than have climatic causes. One of the equipments of a man or woman who goes to the Tropics should be that of a knowledge of cookery. Cooking is an art which belongs to the science of health. Great improvements have, from experience, been brought about in the diet of Europeans in the Tropics. Salted meat and rum no longer enter into their diet, less meat and alcohol and more fruit and vegetables than in olden days having been substituted. For the Tropics the days of heavy luncheons and heavy drinks in the middle of the day are for the most part over, and with them have gone many of the diseases which were attributed to climate. The effects of over-indulgence in alcohol are very marked. Hepatitis and liver abscess, which is otherwise uncommon, occur among Natives who give way to drink, a habit which is not unfrequently associated with other changes in diet, more or less imitative of European customs. The diseases of the liver, induced in Europeans, are more of a chronic nature, for it is seldom that drink is indulged in in quantities, nevertheless, there are in many circles of society, some members who, without taking more than they can apparently stand, take much more than is good for them. Neurasthenia, depression and incapacity for mental work in the Tropics

not unfrequently owe their origin to a consumption of alcohol which would be without any corresponding effect in a more temperate climate.

Drink should Not be Alcoholic.—It is safest for the new-comer to abstain from alcoholic beverages, and especially so if much exposure to the sun is to be endured. Tea or coffee are the customary drinks of many of the inhabitants of the Tropics, and where these are not in use, water is generally the only beverage. It is well to follow the custom of the country in this respect. When alcoholic drinks are used—and they are often found necessary to the European after he has been some years in the Tropics—they should only be taken at meals, and preferably with the dinner in the evening.

CHAPTER II.

WATER SUPPLY.

Rain and Underground Water.

Drinking-Water Supplies and their Sources.—Pure water for drinking purposes is a commodity not easy to obtain in the Tropics. The reason of this difficulty is mainly due to the pollutions to which the water is subjected by the customs of the people, and it is largely owing to these pollutions that microphytic and parasitic diseases are rife. There is not only a greater variety of disease germs and helminthic parasites in warm climates, but the conditions are such as to allow them to flourish in greater luxuriance. Drinking of impure and muddy water in a temperate climate is liable to produce enteric fever, disturbance of the bowels, and possibly worms, while the drinking of impure water in the Tropics is not only liable to produce these diseases, but also cholera, dysentery, anchylostomiasis, bilharzia, guinea-worm and other parasitic affections.

The supplies of drinking water are similar to those in other parts of the world. They are rain, river, lake, spring, well and tank, all being primarily derived from the rainfall. On the ocean, in rainless tracts, and in regions where the rainfall is scanty, or where there are only salt lakes, the drinking water is frequently obtained by distillation. This is the means of supply to the troops and European residents at Aden, where the wells are brackish and where rain may not occur for several years; the sea water is distilled and used for drinking purposes.

In Australia, in some of the mining districts, such as Coolgardie, the rainfall is very scanty, and drinking water, until recently, was obtained from the salt lakes by distillation. The water was placed in large tank boilers, to which were attached pipes leading into expansion tanks which were connected by pipes with receivers. The condensation or cooling of the vapours was effected by exposure of the pipes and of the expansion tanks to as much air as possible. By this method considerable amounts of water were obtained, not in quantities, but two gallons of water per head per day, which was found sufficient for the wants of the miner.

Distilled water is also used on war ships and on other vessels when the ordinary supply which has been obtained from the shore has run short or is unfit for drinking. The distilled water is obtained from sea water by means of Normandy's condenser, which at the same time aerates the water during the process of condensation. As distilled water is flat and unpalatable, aeration of the water is an important process which should form part of the plant in all methods. On board a man-of-war five gallons per head per day is used, but this does not include the quantity of sea water used for sanitary flushing and deck washing.

Occasionally elaborate systems of distillation are to be seen which have been supplemented with charcoal-filters for the purpose of passing the distilled water through these filters. Such an arrangement of filters is altogether unnecessary, and is more likely than not to add impurities to the already purified water.

Search for Water.—In many countries there is no difficulty in obtaining plenty of water by storage from the rainfall, which is abundant, or by a supply from rivers and streams or springs or wells. In other countries it is not a matter of so much ease; still, even in the most unpromising countries it is seldom that water cannot be obtained by boring, if that boring is guided by some degree of discretion as to where it is to be carried out.

In many parts of South Africa, though the rivers are waterless, and at a certain time of the year the surface of the land is arid in appearance, consisting of ironstone, shale and limestone, formed into abrupt and steep rocky hills or kopjes and extensive plains, yet there are few parts in which a boring, if put down by one who has closely observed the general physical features of the country, its lie and its main lines of natural drainage, will not soon strike water under the surface. There are some points which should be borne in mind in the search for water in an unknown locality. Water is more easily obtained in a hilly country than in a plain. The depth of water in the plain depends on the permeability of the upper layer of soil and its thickness before reaching the impermeable stratum which supports the ground water. Any part below the general surface level should be selected for experiment with a driven well.

Water can usually be found under waterless rivers. Sometimes the sandy bed containing the water, instead of being on the surface, lies under a stratum of clay and above the hard substratum of the bed of the river. Water can usually be found also under the dry courses of nullahs, at the junction of ravines and of valleys, and at the foot of hills, but not of spurs ; secondly, in places where there is much vegetation and verdure, or where the water shed is well wooded, which prevents the rain from passing too rapidly over the soil to the water courses. A country cleared of its timber loses its permanent streams, and is subjected to floods and drought. Finally, in the event of there being no vegetation, particular localities over which fogs or swarming insects are noticed in the morning, usually indicate water near the surface. If there is any geological fault in the district it is likely that springs will be found along the line of faultage.

In selecting a camping-ground which is likely to be in use for a considerable time it is important that the water supply shall be permanent. This will probably be

the case if the springs are at the foot of hills. Springs are more likely to be found in limestone districts. Chalk districts usually have few springs unless the level of the locality is considerably below its surroundings. In sandstone districts abundant water is often obtained from deep wells.

The ordinary sources of water supply for drinking purposes may be divided into three groups :—

(1) Rain water.

(2) Subterranean water. (*a*) *Ground water*, shallow wells and a few springs; (*b*) *deep-seated water*, deep wells, artesian wells and most springs.

(3) Surface waters, such as rivers, lakes, ponds and tanks.

Rain Water.—Rain water is a very frequent source of supply, more especially where the rainfall is heavy and the springs are brackish. The rainfall varies greatly in different localities. To take two extreme instances: The rainfall at Cherrapunji in the Himalayas, which amounts to 600 inches in the year, is in striking contrast to that in the rainless tracts of the deserts in various parts of the world. Between these extremes there is every range. The uncertainty of the rainfall in some localities, the length of the dry season, and the large size of the cisterns which then have to be employed, are disadvantages against the use of this source as a supply.

There are *two methods* of collecting the rain; one is receiving it off the roofs into vats or storage tanks; the other is receiving it on a large area of ground which has been rendered impermeable by a covering of slate, concrete or cement (as at Gibraltar), and from which the rain when it falls is conveyed into underground tanks or reservoirs. Of the two methods, that in which the rain is collected from the roof is the more general, the other being adapted for the supply of institutions, barracks, prisons, &c., for which large quantities have to be stored.

In localities in which there is a fair rainfall, and not

too long a dry season, rain water, owing to its purity, aeration, freedom from earthy salts, and absence of liability to be contaminated by reason of its not passing over or through the soil, is palatable, healthy, and well suited for domestic purposes. In determining the amount of water available it is necessary to know the annual amount of rainfall and the superficial area on which the rain falls. In the case of the amount of rainfall this is ascertained by the rain guage, and the supply which is available from a given roof can be roughly estimated by taking the external dimensions of a building, multiplying them together, and multiplying the product by half the rainfall in inches. The result is in gallons, and is not more than 4 per cent. out of the correct amount. An inch of rain delivers per hour 4·673 gallons on every square yard, or 22,617 gallons or 3,630 cubic feet on every acre, *i.e.*, a cubic foot per second on the acre.

Methods of Storage of Rain Water.—At one time in Calcutta the rain which fell on the flat roofs of the houses was conveyed into large earthenware vessels, in which it was stored for domestic use. In Venice until lately, and even now, the rain water which falls on the roofs of the houses and courtyards and streets is allowed to run into underground cisterns, and forms the supply for drinking purposes. These cisterns are made by excavating the soil and lining the reservoir so formed with brick and puddled clay. A brick well is then built in the centre, openings being left at the bottom. The reservoir outside the central well is filled with fine sand. By this means the rain water which is admitted into the reservoir is filtered before it reaches the openings where it can rise in the well. Owing to this filtration and to the fact that there are no draught animals to defile the streets of Venice, the water in the wells is comparatively pure.

In Buenos Ayres the supply used to be rain water conveyed from the roof of the houses into underground

tanks, a method adopted in many places. In Jerusalem there are under the houses large stone vaults or reservoirs into which the rain water from the roof is conducted. Some are provided with sand filters, from which the clear water runs into covered wells.

In Demerara the rain falling on the roofs of the houses is conducted into large vats which are supported on pillars. In South Africa a similar mode of storage is common. There are huge corrugated iron tanks to be seen alongside the house, which receive the rain water from the gutters on the roof. In estimating the size of the cistern the following points have to be borne in mind: (*a*) The amount of water required daily; (*b*) the least, greatest and average rainfall; (*c*) duration of rainless season. The average of twenty years less a third, gives a very fair estimate of the amount of rain in the driest year. The average of the three driest years should form the basis of calculation; and it may be taken that six-tenths, or perhaps safer only half, of the rainfall is available for storage.

Rain falling on a clean surface, supplies a pure water, for, in passing through the atmosphere, it takes up but few impurities except in a large city, but conditions are different when it reaches the ground or roof. In warm countries where dust storms are frequent the roofs of houses are generally polluted with vegetable matter from leaves, animal matter from the excrement of birds, dust containing animal and vegetable matter from the roads, and the eggs of insects. These matters washed into the tanks soon affect the quality of the water, giving it an unpleasant taste, and in some instances causing disease. It is desirable, therefore, that as far as possible impurities from the roof shall be prevented from gaining access to the tank. With this object contrivancies have been made which reject the first washings off the roof, and then afterwards direct the flow into the tanks.

One of the most common contrivances is the leaping weir, which takes advantage of the circling and leaping

character of the flow of water mixed with mineral and other substances, and permits the worst contaminated water to flow past the tank. This arrangement, however, is less effective than small receiving tanks operating a float and plungers, which when the tank is full divert the flow of water into the storage tank. Of English apparatus there is Roberts' and Gibbs' rain separator, but it is liable to get out of order and become useless at the time when most required.

If possible the rain water should be filtered through sand and gravel before it is led into the storage tank. The filtering reservoir should be covered, and the sand should be changed before the rains. It is also an advantage to have several storage tanks, for water, like wine, improves by keeping when undisturbed.

An arrangement introduced by Sir Wm. Macgregor, into Lagos, combines the advantage of storing clean water and protecting it at the same time from mosquito eggs and larvæ.

It consists in using the rain-water pipe for discharging the first rain from the roof, and then diverting the later rain into the water tank. This is effected by the rain-water pipe being plugged at the bottom, where it discharges into the surface drain, and having attached to it at a certain height, an elbow, the pipe of which communicates with the storage tank. The rain-water pipe is attached at its junction with the eaves of the gutter by a dome-shaped netting of 100 strands to the square inch, and at its junction with the elbow that leads to the tank by a netting, the mesh of which is 225 to the square inch. The tank itself is provided with an inspection cover which fits like a camp-kettle lid, preventing surface water and insects getting into it; also with an overflow protected with wire netting of the finest mesh. When the rain comes on the plug is removed from the bottom of the rain water pipe until the roof is thoroughly washed, and the water is pure. Then the plug is re-inserted and the rain-water gradually rises in the pipe until it reaches

the elbow, where it is diverted into the storage tank. The very fine mesh at the junction of the rain-water pipe and elbow furnishes a fine screen, and prevents any suspended matter from gaining access to the water in the tank. If the storm continues after the tank is full, the service tap is opened and the tank is thoroughly flushed.

Situation and Kind of Storage Tanks.—The situation and the kind of tank in which the drinking water is stored are important matters for consideration. The tank is best placed above ground and on a platform. Each gallon of water, at a temperature of 60° F., weighs about 10 lb. The tank should be under a roof to protect it from the sun, in order that the water may be kept as cool as possible, and also to exclude light to prevent the growth of vegetation; it should, moreover, be covered, in order to prevent dust, insects, rats, and other objectionable things from gaining access. With the knowledge now gained as to the rôle of the mosquito in acting as the intermediary host of the malaria parasite, it is obvious that in all malarious countries reservoirs for the storage of water should be protected from the mosquito. It is usual to find the water-butt full of mosquito larvæ. This can easily be avoided by mosquito wire-netting covers, which at the same time prevent other insects getting into the water. It is not sufficient to have wire-netting covers for the tanks. The protection thus afforded must extend to the inlets and outlets of the tanks, and to the down pipe which brings the water from the eaves of the gutter to the separation tank, or other contrivance that may be used to prevent the first washings of the roof from flowing into the tank. The mesh should be at least 100 strands to the square inch, if it is to be effective. When the reservoir or tank is underground care must be taken that there is no leakage into it, and care should be taken always whether above or below ground, that the overflow pipe discharges freely into the open air and not direct into a sewer. It is important that the reservoir be situated in such a position as to be

easily inspected, and that it shall be of such construction and size as to allow of being completely emptied and cleaned out. There should always be at the lowest part of the tank an arrangement by which all the water can be drawn off and the tank thoroughly cleansed. All cisterns should be periodically inspected and cleaned. Vats of wood are objectionable because they are subject to decay, and to be covered, too, with vegetable growth. Lead cisterns should never be used to store water, and especially rain water, which on account of its softness has a peculiarly solvent action on the lead, which even in the smallest quantity is poisonous; a larger proportion than a milligramme per litre is poisonous. Concrete, cement, slate, and stoneware reservoirs are good, and so are corrugated iron tanks. Perhaps the easiest of construction are tanks made of bricks laid in cement. Common mortar should not be allowed to come in contact with the stored water, as lime is readily taken up by the water. In all cases rain water stored in this way should be boiled or filtered before being used as drinking water.

Subterranean waters form another source of water supply. When rain falls on soil which is permeable and which is more or less horizontal in the arrangement of its layers, the water percolates down to the first impermeable layer, where, not being able to get lower, it forms a reservoir called the underground or soil water. When the layers are not horizontal, but inclined and dip down deep into the earth, the water falling on the outcrop, or that part of the layer which comes to the surface, passes down to greater depths, underneath the impermeable layers near the surface and there forms deep subterranean reservoirs.

Accordingly, the underground reservoirs are not all at the same depth, and there are usually a series of reservoirs one under the other, nor is the most superficial reservoir always at the same depth. Their formation depends on the permeability of the soil on which the rain falls, the

thickness of the permeable soil, the amount of rainfall and the presence of an impermeable layer holding up the water. They may be quite close to the surface or at some considerable depth.

Springs.—These underground reservoirs may be retained in natural basins, or find, as they generally do, an outlet into the sea or into a river or lake, or by a spring at a lower level. This underground water is in constant movement along a water course, or towards the nearest water course or sea. The rate of flow is very slow.

Whenever the underground waters discharge themselves spontaneously at the surface of the ground they form springs. This may be due to the impermeable stratum which holds up the water cropping out at a lower level, or to the surface of the ground dipping down suddenly, which causes it to dip below the highest level of the underground waters. In the first instance the spring is constant. In the second it may be intermittent, for as the level of the ground water is subject to fluctuations, the lowest level of the water may not reach above the dip in the surface of the ground. The level of the underground water is constantly changing according to the season, rainfall, discharge from springs, and other causes, such as the variation in the level of the water in the river or sea into which it discharges. Sometimes the fluctuations are very great; thus in Calcutta there is a fluctuation of from 5 feet to 15 feet. Springs when derived from underground waters of considerable depth generally supply pure waters. It is only exceptional and rare that such waters are contaminated by impurities carried down cracks and fissures in the rock. On the other hand, springs whose source of supply is from limited or superficial strata of subsoil of sand or gravel may furnish an impure supply if the soil on the surface becomes polluted in any way. Examples of such pollution were constantly to be observed in the South African war, in which superficial land springs supplied pure water so long as the soil from which they were derived

remained free from pollution, but which became highly impure and dangerous when troops encamped on the ground, or when large numbers of horses were tethered there. In some dead animals were putrefying immediately above the springs. In civil life, subsoil water-supplying springs or wells may get contaminated in a similar way by large numbers squatting over the ground, as occurred when the Maidstone water supply was polluted by hop-pickers encamping over the sources of supply, or it may get contaminated by the fields being manured, or having large heaps of manure placed in them, the drainage of which is, during rains, carried into the subsoil water.

The rain-water, as it passes through the soil undergoes certain important changes, dependent on the nature of the soil and the amount of organic matter it contains. New constituents are added to the water.

The area forming the source of land springs or springs derived from superficial sand and gravel-beds should be protected from defilement of any kind, and this protection should also extend to the immediate surroundings of the spring. The protection can be secured by fencing and the diversion of any drainage within this area which may come from suspicious sources or cultivated fields.

In the case of camps during war or peace, or in the case of large pilgrimages where crowds of people are brought on to a given area, perhaps for several days or weeks, and they are dependent on subsoil waters for drinking water, the greatest care should be taken in the selection of the springs or wells to be used, that sufficient protection of the sources be secured before the pilgrims arrive; for no ground can remain for long sweet when occupied by large crowds, and should heavy rains occur during the gathering, the rate of percolation through the soil will be so accelerated that the bacterial and chemical action going on in the soil will be unable to efficiently purify it, and if the protection recommended has not

been secured, the purity of the water in the wells and springs will soon be affected.

Dempster demonstrated that it is possible for the cholera bacillus to be carried down through two feet and a half of porous soil by a current of water.

Wells and their Classification.—There are several kinds of wells, such as shallow wells, deep wells, and artesian wells. *Shallow wells* are those which tap the underground water, overlying the first impervious stratum. *Deep wells* are those sunk through an impervious stratum and tap the deeper water-bearing strata. *Artesian wells* are those which are sunk through impervious strata down to a water-bearing stratum in which the water is under sufficient hydrostatic pressure to be forced to the surface when the well is formed.

With this classification shallow wells may be of considerable depth, depending on the thickness of the water-bearing stratum, the height of the underground water and the depth of the underlying impervious strata. They may vary from 2 or 3 feet to 50 or more feet in depth. Deriving their supply from the ground water, the pumping of a shallow well affects the ground water in every direction for a measurable distance. This *circle of influence or of drainage* increases with the demand upon the well, forming a cone having its apex at the well water and its base on the surface of the underground water. The radius of the base varies in different soils. In those soils that allow of a free passage of water, such as coarse gravel, the distance may be one hundred to two hundred times the depression in the well. In fine sand it may be only twenty to forty times the depression.

Sources of Contamination of Shallow Wells.—A cesspool, privy, manure heap, or other contaminating agent within the circle of drainage is likely to be dangerous. The cesspool may thus drain directly into the well if there are fissures or cracks in the soil as is likely to be the case in hot and dry weather, and if there are no cracks or fissures it may do so when the soil becomes saturated

with filth and loses its purifying power. If the amount of liquid filth escaping from the cesspool is too small to drain directly into water supplying the well, but only pollutes the soil above it, the filth in the soil is apt to be washed into the well on the occurrence of rain. This explains why some wells are noticeably bad after heavy rains, while at other times the water seems to be good. On the other hand, when there is a more direct passage of filth into the well heavy rain may so dilute it as to cause the water to be purer than in dry weather.

The circle of drainage is not always the circle of possible contamination. The movement and direction of the ground water are important. If any offensive matter pollutes the underground water as this flows towards the well it may, especially in a chalk soil liable to fissures, be dangerous, whereas pollution occurring after the underground water has flowed past the well causes no danger to that particular well. Contamination produced in this way may come from a considerable distance, and especially is this the case in chalk formations where fissures in the chalk allow of a ready transit of the polluting matters from cesspits to wells a quarter of a mile or more away.

A rise in the underground water after heavy rains may also reach pollutions which at other times were beyond the reach of the well.

Other sources of contamination are from the surface, and they are the most important as well as the most frequent. A pollution that has to pass through the soil undergoes a certain amount of filtration, which in a large proportion of cases is sufficient to filter out pathogenic germs, but the pollution that finds its way directly into the well from the top, reaches the water in its most potent condition. A well which has not a protecting parapet, even when covered, is a dangerous well. A well of this kind is frequently placed on the lowest ground and receives surface drainage or flood water which flows from the higher ground into it; or if it is inside the house

it often receives the sulliage water. When the well is covered and has no parapet, as is seen in fig. 1, which is a common arrangement in South Africa and elsewhere, it is no better protected than when it is uncovered, for the surface drainage gets into the well just as easily, and fowls, and dogs and cats carry on to the loosely fitting covers filth from any manure or refuse heaps, privies,

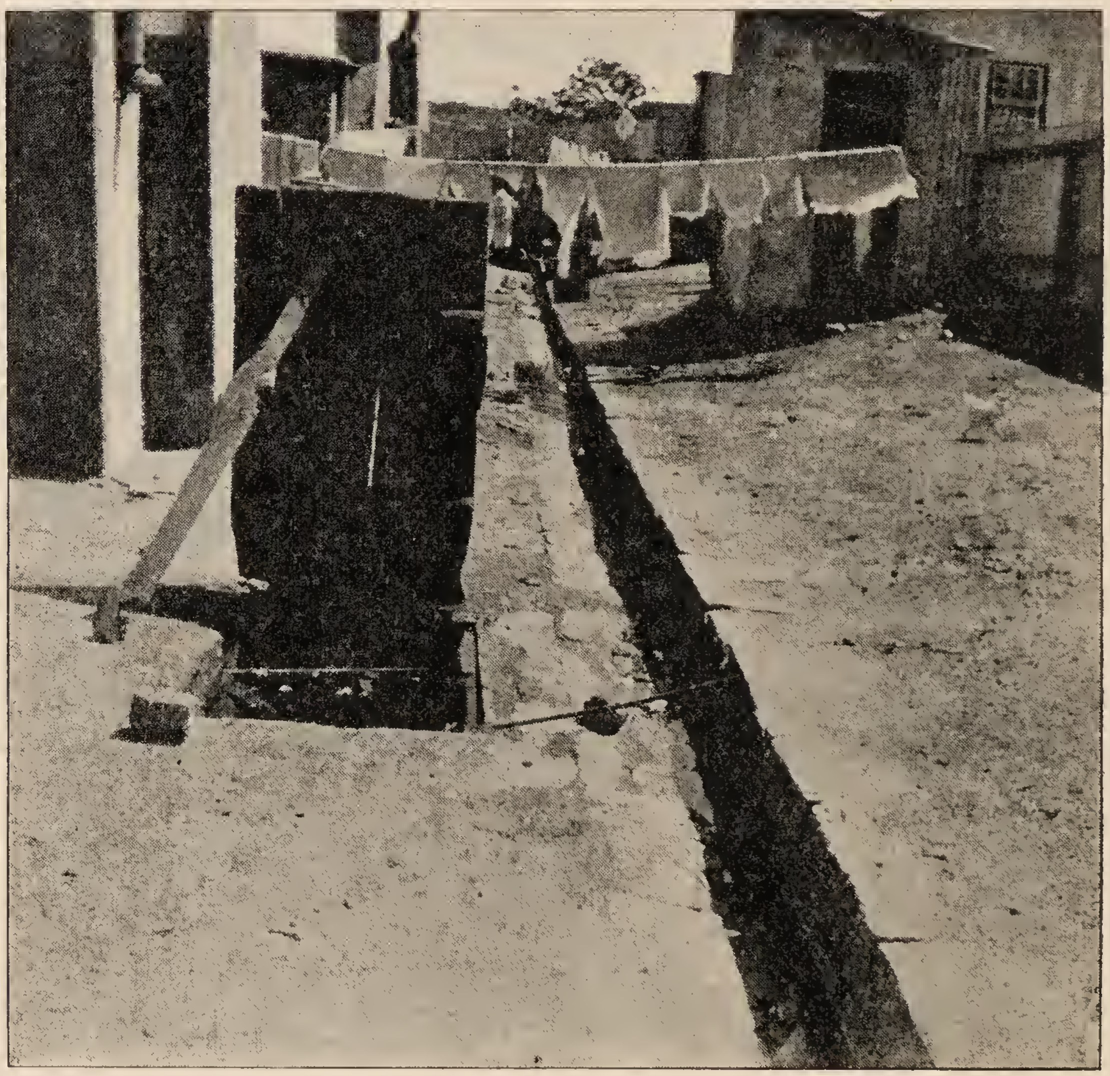


FIG. 1.—Covered well in Seven Sisters, without parapet and liable to contamination. Stand-pipe under clothes-line. Row of privies on right. Two-foot rule in foreground.

stables, or other sources of contamination that may be close by, and much of this filth ultimately finds its way into the well.

In India the mouth of the well is the favourite spot for ablution, and it is not infrequent to see one person

drawing water for drinking purposes while another is performing his ablutions, and the soiled water is flowing back to the well. The same is to be seen in China, though here the impurities are unlikely to be so great from this source, as the Chinese do not wash to the same extent as the Indians, and the effect of the impurities is lessened by the habit of drinking tea instead of water.

The Objections to and Dangers of Shallow Wells.—The great objection to shallow wells is their liability to pollution by cesspools and by surface drainage, and by their consequent liability to specific pollution. A large proportion of the outbreaks of typhoid fever recorded is due to the use of shallow wells. Of 205 epidemics of typhoid fever in Great Britain and Ireland, prepared by the late Mr. Ernest Hart, nearly two-thirds were due to the use of ground water, and nearly all of these were due to the use of water derived from shallow wells situated within a few feet of defective cesspits, cesspools or sewers. The liability to pollution of many of the wells in Great Britain and Ireland is undoubtedly great, but it is immeasurably greater in the Tropics. In the East there is no sense as to what a pure water means. The cleanest individual who will not be satisfied unless he washes himself several times a day will have no compunction in drinking water of the most impure kind. The wells are contaminated in the Tropics by cesspool pollution and by surface contamination. In many places cesspools are quite close to the wells, and when one cesspit is filled another is dug. Before Buenos Ayres was drained and a water supply given to the town, the cesspits at the back of the house, and only a few yards from the rain-water reservoir, or well in the court-yard, used often to be so numerous that it was not safe to walk across the back-yard.

The construction of cesspits of any kind is often too much trouble; in that case fæcal pollution is generally caused by surface drainage into the well, which is con-

taminated by the contents of the privies or drains, which when full are emptied on to the garden or ground near the well. This was the position of affairs in Bloemfontein before a public water-supply. The situation of wells and their liability to surface pollution are well

FIG. 2.—Well with bath and washhouse on one side. These are covered with old galvanized iron, old rail, &c. Tubs where horses and cattle stand and drink. The drainage runs back into the well.

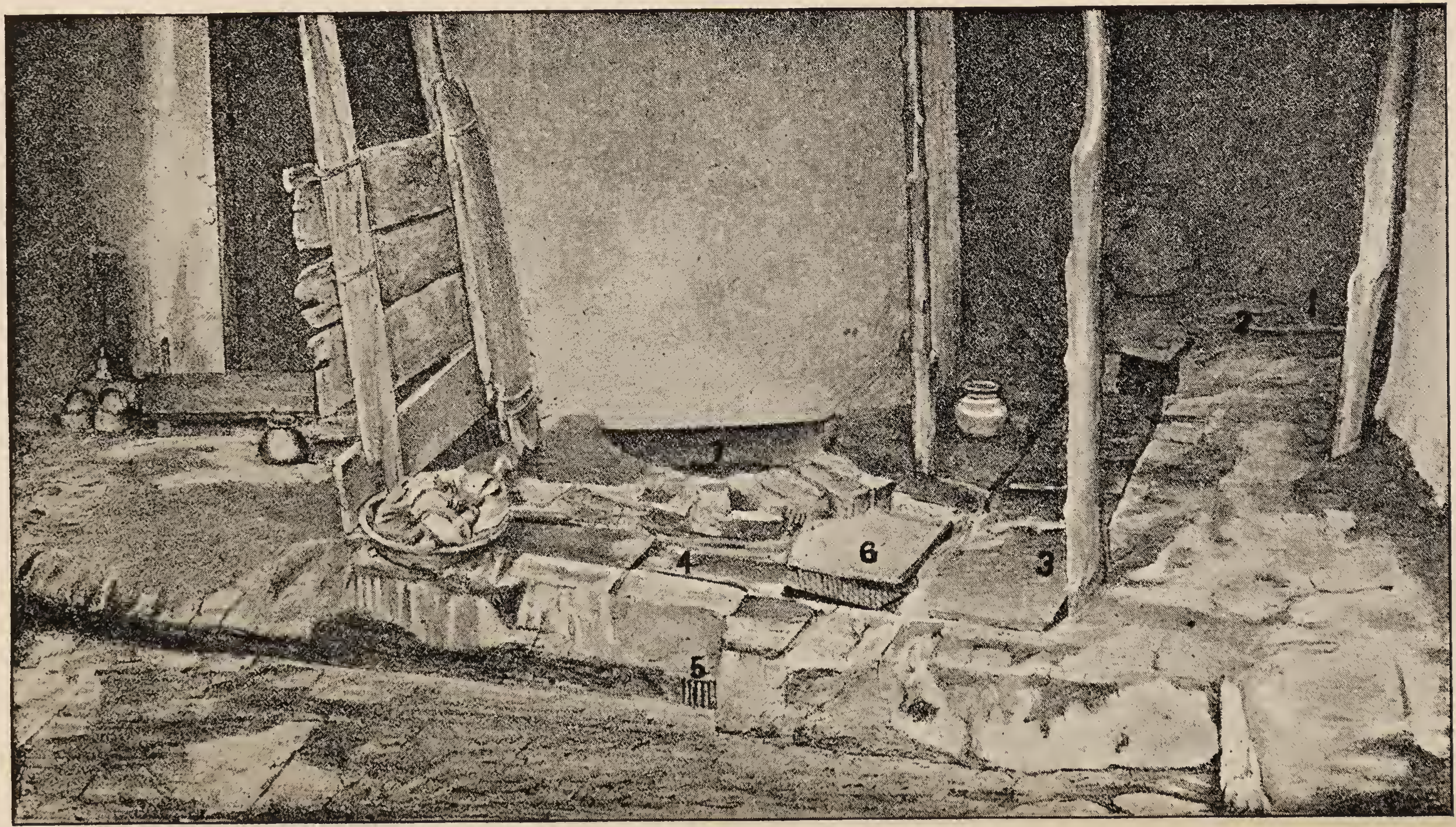
depicted in figs. 1 and 2. These are average samples of what may be seen any day in different parts of India and Burmah, or, as a matter of fact, in any part of the world.

ILLUSTRATIONS SHOWING CONDITION OF COMPOUND OF A HUT INHABITED BY TWENTY-SIX PERSONS AND IN WHICH THREE DIED OF CHOLERA.

1. Entrance to Privy. 2. Drain, covered with tiles leading from Privy. 3. Continuation of drain No. 2. 4. A second drain, covered with tiles, leading to gullypit. 5. Surface grating, taking off water from compound into gullypit. 6. Gullypit, close to well and into which the several drains discharge, and which is connected with the underground drainage of the locality. 7. Well, surrounded by broken drains.

To face p. 38.

ILLUSTRATIONS SHOWING CONDITION OF COMPOUND OF A HUT INHABITED BY TWENTY-SIX PERSONS AND IN WHICH THREE DIED OF CHOLERA.



1. Entrance to Privy. 2. Drain, covered with tiles, leading from Privy. 3. Continuation of drain No. 2. 4. A second drain, covered with tiles, leading to gullypit. 5. Surface grating, taking off water from compound into gullypit. 6. Gullypit, close to well and into which the several drains discharge, and which is connected with the underground drainage of the locality. 7. Well, surrounded by broken drains.

Universality of Contamination of Wells.—My experience leads me to the conclusion that much the same kind of wells, and more or less the same kind of contaminations, are to be found in every part of the world. In the Tropics wells and cesspools are close companions, but the most common mode of pollution is from surface drainage passing into the mouth of the well, the drainage having as its polluting source surface excrement and sulliage and decomposing animal and vegetable matter in the neighbourhood of the well.

On inspecting a well the proximity of burial grounds, cesspools, sewers, latrines, surface drains, manured fields, and filth nuisances, should always be borne in mind as possible sources of pollution. In India and in Mahommedan countries burial grounds are usually so numerous and kept in so insanitary a condition that they are a considerable danger to the well water.

Tube-Wells and their Advantages in the Tropics.—It is because of the general surface defilement and the peculiar habits and customs of the coloured races of the Tropics that Norton tube-wells, or Abyssinian wells, as they have been called, are so useful. They are particularly advantageous for villages, isolated houses, and camps where the soil is porous and the water within 25 feet of the surface. They overcome most of the dangers which are apt to arise from an ordinary shallow well, and, if care be taken as to the situation in which they are placed, a supply of good and pure underground water may be obtained which would be almost impossible with an open well. They have a further advantage, that it is impossible for mosquitoes or other insects to reach the water contained in them. The tube-well may be made to tap the ground water overlying the first impermeable stratum, or it may be sunk below the impermeable stratum to a second water-bearing stratum and tap the water contained in this. The tube-well consists of an iron tube or pipe of $1\frac{1}{4}$ to 4 inches in diameter, having at its lower end a wrought-iron or steel point. Above this point the

tube is perforated for some distance to admit water. At its upper end it is so constructed as to allow of another tube being coupled on to it. The tube-well is driven into the ground by a weight arranged on a tripod. When the top of the first tube reaches the surface a second is joined on, and so the driving and joining on of tubes are continued until water is reached. A pump is then attached to the top of the tube (fig. 3). The pump will yield about 7 gallons per minute. The water at first pumped

FIG. 3.—Water-boring operations on a farm in South Africa. Water flowing 16 feet above the surface. Yield 70,000 gallons per twenty-four hours.

up is muddy, but if the pumping is continued it will clear as the *débris* is brought up. The yield of a tube-well may be taken as follows :—

Size of tube in inches	Gallons per hour
1¼	150 to 600
2	300 ,, 1,200
3	600 ,, 2,400
4	1,200 ,, 4,400

In America and in some parts of India several tube-wells are connected, and in this manner a large supply may be obtained. These tube-wells prevent pollution from any surface contamination, and as such they are most useful. In order to prevent possible leakage down the outside of the tube, a small ring of cement may be made at the surface, which is also useful in fixing the tube so that by the action of the pump the soil is not loosened. One great advantage in the use of tube-wells is that they can be shifted from place to place, and are thus exceedingly useful in ascertaining where sweet water is obtainable, which is often difficult in localities where sweet and brackish waters are near one another.

Sullivan's Diamond Drills.—Another form of tube-well is the bore-well made by a diamond drill or jumper worked either by hand or by steam. The diamond drill or jumper is used for sinking bore-holes through hard soil or rock.

The advantages of a bore-hole are :—

(1) Freedom from surface contamination.

(2) Natural filtration.

(3) Rapidity in sinking. The average rate of sinking an ordinary well of about 6 feet in diameter is 3 feet per twenty-four hours, whereas with a bore-hole the average is 28 feet during the same period.

(4) A greater quantity of water is obtained by sinking a bore-hole than by sinking a well.

In an ordinary well when the superficial water is tapped the deepening of the well is generally abandoned, owing to the inrush of water being too great to allow of the continuance of the work, and consequently it is usual to be satisfied with the superficial supplies.

Protection of Wells.—If water is to be taken from *shallow wells*, the ground-water level should, if possible, be not less than 12 feet from the surface, and the ground on which the well is situated should be quite clear around for at least 100 feet.

Wells should be lined and cemented or cased, shallow

wells to below the water level, deep wells to below the first impervious stratum, so that no surface water can enter without having first filtered through a certain depth of soil. They should be further protected from surface drainage flowing in at the top by having around them a raised parapet, which should be covered to prevent light or dust getting in. A suction pipe should be provided, not immediately over the well, but at the side, the pipe attached to the pump and the well being so arranged as to admit of this (fig. 4). The ground near the mouth of the well becomes dry in the summer, and is apt to crack and get fissured, allowing unfiltered water to leak into the well. This may always be avoided by concreting a certain portion round the well and sloping it away from the well. At least 12 feet round the well should be treated in this manner. A drain at the outer side of this sloping portion and discharging away from the well will prevent the surroundings of the well becoming boggy.

If a pump is not used, but cattle are employed for drawing the water, the circular path on which they travel must be drained away from the well and kept clean.

Another method of protecting a shallow well from pollution is to provide it with an iron pipe, which shall reach from the bottom to the top of the well, then to fill the well up to the highest water level with pebbles and gravel, and the remainder to the surface with sand. The well can be thus turned into a tube-well, with the advantage of its lower end dipping into a layer which gives no resistance to the subsoil water. The pump, as in the other case, should not be erected immediately over the well but at some distance from it, which will prevent the water of the well, when used for washing and other domestic purposes, leaking back into it and rendering the water foul. This kind of well is safer for the Tropics than that which is covered and has attached to it a pump.

In deep wells and springs the filtration through the soil has been so complete as to render the water very free of organic matter. The same care has, however, to be taken

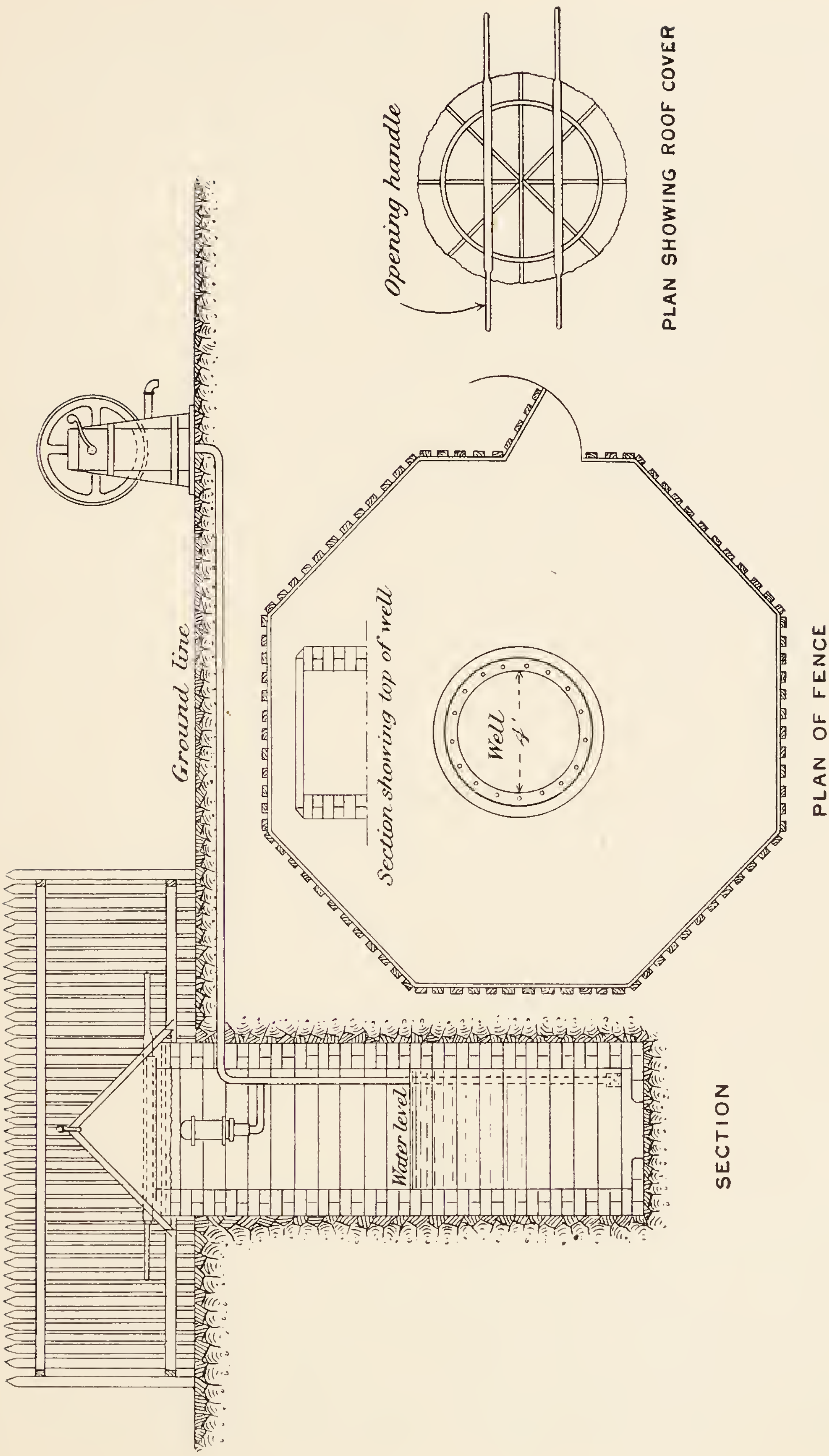


Fig. 4.—Plan of Protected Well suggested by Sir William Macgregor.

as regards drainage from surface defilement flowing in at the top of the well. Besides the immediate surroundings of a deep well being carefully protected, attention should be paid to the sanitary condition of the outcrop or gathering ground, which is likely to be at some distance from the well.

Artesian wells have had their water filtered through such a depth of soil that provided they do not contain an excess of mineral matter their waters are very pure. They are used in many places in the East. In Pondicherry there is a very deep well, and it is due to the purity of its supply that Pondicherry is so free from cholera. In Java there are a number of Artesian wells, some of them being sunk on the seashore underneath the sea. Since their introduction cholera has lost its epidemicity in Java. In Queensland many artesian wells have been sunk, and supply large quantities of water in localities which were formerly waterless. They are often 1,500 to 2,000 ft. in depth.

Methods employed for Discovery of Suspected Sources of Contamination.—It is important, when a well water is found by analysis to be polluted, to discover the source of the contamination, which may be situated at a considerable distance. For this purpose an inspection is necessary. Too much importance cannot be attached to this inspection. A chemical and bacteriological analysis may be informing as to the condition of the water at the time of analysis, but it will give no information as to the liability or not of pollution or the manner in which it is polluted. Frequently an inspection will save the trouble of an analysis, for a contamination which is evident to the eyes does not require an analysis to prove it. This is a point which has to be particularly borne in mind in tropical countries where apparatus and reagents for analysis and bacteriological examination of water are rarely at hand.

The purity or otherwise of the water of a well or land spring and its liability to contamination can generally

be determined by a thorough inspection. When this inspection leads to a suspicion that the contamination is from a particular source, this suspicion can be confirmed or otherwise by the employment of one or other of certain substances as tests. Common salt, chloride of lithium and fluorescin are the principal soluble substances employed as tests, and they are applied to the suspected source and then looked for in the water. Before using common salt or chloride of lithium it is necessary to examine the water to ascertain that it does not naturally contain these salts. The same substances can be used for the detection of the insuction of subsoil water into defective bore wells and leaky water mains. If common salt is employed it is detected by the extra amount of chlorine in the water shown by the nitrate of silver test, but large quantities are required which are not often available. The lithium chloride is traced by evaporating a quantity of water, and flaming the residue which will give to the flame a crimson colour visible to the eye or in the spectroscope. The test is extremely delicate in detecting minute quantities of this salt, one part in a million being recognisable under favourable circumstances. It is wiser to use ten times this proportion, which, however, causes the test to be a very expensive one. In determining whether the sewers of Calcutta leaked into the subsoil water in which there were wells supplying drinking water, it was found that the introduction of chloride of lithium into the sewers temporarily blocked up caused the water in the subsoil and adjacent wells to give the spectroscopic band for lithium, which was absent previous to the experiment.

Fluorescin or resorcin thallin, which is an orange dye with a remarkable green fluorescence in solution in water, is superior to common salt or chloride of lithium as a test, and has the additional advantage of not requiring any previous examination of the water to detect its presence. It does not occur naturally in drinking waters. An excellent example of the value of fluorescin in tracing the

course of an underground water is the instance quoted below in which it was employed by Dr. Copeman. The colour fluorescin produces is so diffusible and brilliant that one part of fluorescin is capable of colouring or rendering fluorescent at least 100 million parts of water. One quarter to half a pound dissolved in water and poured on to the suspected source of the contamination, whether it be a manure or refuse heap, drain, privy, cesspool, or other object in or on the ground, will, if there is any communication as suspected between this and the well, show itself in course of time in the well by giving to the water a fluorescent tint. In order to facilitate the passage of the solution of fluorescin from the suspected source of contamination to the well, large quantities of water should be poured after the fluorescin, and the well should be pumped so that the flow of the drainage is towards the well. If the well water becomes green, suspicion becomes a certainty. The green colour can be made to disappear by adding some bromine which forms with the fluorescin a yellowish red solution of eosine. An important point is that the fluorescin will give no colour in acid water, so that if in its passage to the well the solution became acid in any way or the water to be tested were acid, no colouration would be given. This, however, is of the rarest occurrence. But to avoid this possibility, caustic potash is often added to the fluorescin before use or may be added to the samples of water when searching for the fluorescin after it has been poured into the suspected sources.

In 1905 Dr. Copeman made use of fluorescin to test whether a sewage farm belonging to the County Asylum of Cambridge, and on which the sewage of the Asylum was treated by broad irrigation, could possibly contaminate the two wells supplying the Asylum with drinking water. The wells were 1,200 and 2,500 feet respectively distant from the sewage farm. The reason of the investigation was a series of typhoid fever cases at the Asylum. The geological stratum of the district

consisted of chalk underlying a thin stratum of loam. By digging through the loam on the sewage farm down to the loam, and pouring five pounds of fluorescin dissolved in water and caustic soda into the hole or trench, a positive result was given. In less than five days the fluorescin was found in the first well, and in nine days in the more distant wells.

Dr. Thresh has used ammonium chloride with satisfactory results, but this, like the sodium chloride, requires chemical testing of the water before and after its use. Seven pounds of ammonium chloride is stated to have its ammonia readily detected when dissolved in one million gallons of water. Petroleum is sometimes poured on the ground surrounding a well to ascertain if there is any direct drainage from the surface to the well. Sometimes the source of contamination of a polluted well is discovered accidentally. Instances have occurred in which, owing to sickness in the house, carbolic acid has reached the cesspool and from there percolated into the well, so that the first suspicion of anything being wrong with the well has been the taste and smell of carbolic acid in the water.

CHAPTER III.

WATER SUPPLIES.

SURFACE WATERS.

SURFACE waters form a common source for water supplies, and vary in quality in the highlands and plains. The whole of the rain which falls on the ground does not percolate into the soil to form the underground reservoirs referred to. A certain quantity is evaporated and the rest flows along the surface into the natural drainage channels of the country, forming lakes or rivers. The surface water derived from that portion of the rain which falls on the highlands of a country is generally, by reason of the sparsity of the population, very pure, but in its course down the hills and over the rocks it dissolves both mineral and vegetable matter and takes up micro-organisms and insoluble substances. If these are not in excess the water retains its excellence. It may, however, as is the case when it emerges from dense forests, contain an excess of vegetable matter, or, as in Darjeeling, the hill station of Bengal, take up in its downward course over the rocks a large amount of mica. Both these substances are apt to cause intestinal irritation and diarrhœa, but they can easily be got rid of by filtration, and in the case of vegetable matter its injurious influence can be prevented by boiling the water when there is no means of filtration.

Lakes, Natural or Artificial, containing Upland Waters give the purest supply for towns and are preferable generally to river water for drinking purposes. The

purity of lake water is due partly to the fact that bacteria and other suspended matter subside, the large expanse of water permits of free oxidation, and the light destroys bacteria near the surface, and partly to the fact that much of the lake water is supplied by the underground water which discharges into it. This underground water has undergone a natural filtration which renders it very pure. The still water, however, favours the development of the lower forms of plant life, such as *algæ*, which must be removed from the drinking water by screening and filtration.

Artificial lakes are often formed by building a dam or barrier across one of the principal streams which brings down the upland waters. The Bombay water supply is an excellent example of pure water obtained in such a manner, so is that of Hong-kong. Both supplies, more especially the former, exhibited at first the peculiar taste and appearance so usual in water from newly-constructed reservoirs, which at a later period disappeared. The water so impounded gradually acquires the character of lake water. At first, owing to the flooding of land, which was previously either cultivated or covered with vegetation, the plants die and give to the water a disagreeable appearance and taste, but usually this gradually passes away, the water in the lake becoming purer as time goes on.

The Growth of Algæ and their Effects in some Reservoirs.—But this is not always the case, and the objectionable odour, taste and appearance of the water generated by algæ and decaying vegetable matter may tend to render the water unpotable at certain seasons of the year. The disagreeable taste and objectionable appearance which sometimes exist in waters derived from lagoons or swamps in which rushes grow are often of a very persistent nature. An instance of this is the water supply of the Mauritius, where great difficulties have been experienced because of the lagoon which supplies the drinking water containing immense quan-

4

tities of vegetation, notwithstanding constant dredging (see p. 73). A similar difficulty has been experienced in the artificial lake at Singapore, which derives its water primarily from excellent gathering grounds. The difficulty is increased by the nature of the soil which is laterite, *i.e.*, an ironstone clay, which breaks up into a finely divided state, and is detrimental to the filters.

The plants which grow in the shallow parts of tropical lakes, mostly consist of a species of Chara, Utricularia, Blysca, and Euhydrias. Undisturbed they grow rapidly. The Chara always grows under water, its upper part being about a foot below the surface. It is seldom found in parts of the lake deeper than 8 to 10 feet, usually at a less depth. The Utricularia grows on the surface of the water. The Chara has a disagreeable smell in its natural state, while the others cause the water to become offensive by their decay.

In certain American lakes and storage reservoirs a minute fresh water sponge, the *Spongilla fluviatilis*, has been found to give rise to a cucumber taste and smell, and certain species of Nostoc and other algæ in a state of decay to a pig-pen odour. Crenothrix, *Cladothrix dichotoma* and *Beggiatoa alba*, may also give to a water supply a disagreeable odour and taste. A water of this description sometimes develops an offensively fishy smell after filtration.

Ground waters which are excellent supplies on account of their purity are liable, owing to containing suitable mineral food when stored above ground in uncovered reservoirs, to be a favourable medium for the excessive growth of algæ, giving to the water a disagreeable and nauseous taste and smell. It is therefore always advisable to store underground waters, if such storage is necessary, in covered reservoirs.

Mason gives an instance of this liability of deep-seated waters to the development of algæ when exposed in open reservoirs as opposed to the less liability in the case of surface waters which presents a striking con-

trast. At Atlantic City, New Jersey, there are two supplies which are stored separately in basins about the same size, and separated one from the other only by a narrow embankment ; later the supplies are mixed. One supply is derived from wells and is delivered into the reservoir from the bottom, and always contains large masses of green growth. The other reservoir with surface water brought in by a canal is entirely free of growths of any kind.

To prevent aquatic plants growing and afterwards decaying, which is likely to occur in shallow water, the water in the reservoirs should be at least in every part 12 or 15 feet deep. This applies to the sides as well as further out in the reservoir. If it is an old reservoir and deepening out of the question, then the water should be kept clear of vegetation by regular dredging and removal, and the occasional use of sulphate of copper in the strength of one in a million. The usual method of application is to place trays of sulphate of copper over the sides of a boat and row across the lake in different directions until the measured quantity to be applied has been dissolved. Possibly a better method of application would be to add it to the water at the different surface inlets to the lake. The treatment of water for the removal or control of deleterious algæ should not be confounded with the much more complicated question of treating waters by the copper method for the destruction of the typhoid and colon bacilli. In constructing new reservoirs it should be set down as essentials first, that the sides should descend rapidly to 12 or 15 feet, and not slope gently to that depth, for with the fluctuations of the water level the latter condition is very favourable to the luxuriant growth of aquatic plants, and to their decay, both of which are to be avoided in providing a potable water ; and secondly, that the whole site including sides and bottom of the reservoir should be cleared of bushes, scrub, trees, stumps of trees, peat, filth, loam and other organic matter, before any water is admitted into the

reservoir. Everything should be uprooted and removed, and even a layer of soil of possibly a foot in thickness should be taken away so as to free the bottom as much as possible of organic *débris,* for, apart from algæ near the surface deteriorating the water, it happens that when the lower layer of water is brought in contact with decomposing organic matter the dissolved oxygen becomes used up, and extractive matters are dissolved which give to the water a foul odour and a black colour. Such measures are accordingly necessary to secure a palatable water from the commencement and to remove the difficulties otherwise entailed. A systematic inspection of lake or impounded reservoir supplying a water supply should be regularly made by the health officer and engineer, with the object of seeing that the water is free of deleterious vegetation, and that the surroundings and tributaries are in a clean condition. If any new works have to be carried out above or near the reservoirs special attention should be paid to the housing of the coolies, and means should be at once taken to divert the drainage so that there may be no possibility of contamination. A medical surveillance should also be kept over the coolies until the work is complete and the area has been evacuated, in order that cases of cholera, typhoid fever, dysentery or other water-borne disease may be detected at once, and the patient isolated. It is never safe to have large gangs of coolies working near reservoirs or constructing new reservoirs without strict medical supervision.

Upland streams are often diverted into specially constructed reservoirs or the high lands are tapped by superficial land drains which receive the water that has partly penetrated into the soil, and which convey it into reservoirs.

Purity of surface water in Reservoirs depends on certain conditions relating to the gathering grounds, and to the surroundings of the reservoir. In order that surface waters collected from gathering grounds shall be pure, it is

necessary that the land within the area of collection should not be cultivated, and if possible little inhabited. The Melbourne water supply is obtained from gathering grounds in the highlands nearly 50 miles from the city. In 1888 I had the opportunity of inspecting the gathering grounds there when typhoid fever was prevalent in Melbourne. The condition of affairs, since altered, I believe, fully explained the prevalence of typhoid. The inspection revealed the fact that, though sparsely populated, the lands around and adjacent to the reservoir were cultivated, and were a source of pollution, while the open conduits which brought the water into the town from the reservoir were subject to contamination from surface drainage. In Penang, water is obtained from gathering grounds in the hills subject to pollution from the drainage of houses in the hill station, and from much mineral matter. Wherever such conditions exist in the Tropics, and the water is not purified, dysentery and diarrhœa are prevalent.

All surface supplies should have their gathering grounds regularly inspected to secure purity, and for this purpose it is necessary to follow up the streamlets and their branches from which the water is derived, and to note that from their source to their entrance into the reservoirs there is no possibility of sewage, drainage, or dead carcases polluting the water. In some places there are two sets of reservoirs, one well out in the country, the other within the town, the former being the supply tank to the latter. It is not infrequent to find that great care has been taken over the prevention of contamination of one, generally that which is well away from the town, while the same precautions for the other are omitted. It is obvious that under these circumstances the want of precaution in the one neutralizes the good effect of careful precautions in the other. Instances are numerous in which town reservoirs have been placed in small gardens with the ground sloping towards the reservoir, and with the roads subjected to pollution, while the

gardens have been the favourite resort for picnics. Under these conditions the first shower of rain brings contamination into the drinking water. Examination of such waters after a shower of rain has shown a marked increase in the chlorine, albuminoid ammonia, and bacteria. It is false economy to be sparing in the amount of vacant and reserved land around a reservoir in or near a town, and it is dangerous not to so protect it as to render contamination impossible.

Gathering Grounds should, if possible, be Wooded.—It is important that the gathering grounds in the Tropics should be planted with trees, with a clear space of at least 100 yards around the reservoir. Many reservoirs have trees up to their banks but the falling of leaves and branches into the water only adds to the amount of decaying vegetable matter and increases the difficulties of purification. Trees in the gathering ground prevent the rain as it falls on the ground pouring down to the reservoir in torrents, and secure a steady flow. There is under the latter conditions less danger to the reservoir, and a greater supply of water to fill it, for should the water come down in torrents the reservoir is subjected to much stress, quickly filled up, and large quantities of water run to waste. Gathering grounds that are bare of trees and vegetation supply during the rains an immense quantity of silt which it is always very important to avoid.

In selecting a gathering ground the future extension of the population has to be borne in mind. Cultivated fields have to be avoided and the area should be uninhabited. There should be no swamps in it, and if swamps exist they should be so drained that the rain will flow off them quickly, or they should be excluded. The presence of peat in gathering grounds is likely to so affect the water as to render it particularly solvent of lead, should the water be distributed to the houses in leaden pipes. The peaty formations on the collecting areas should, if possible, be excluded. When they cannot

be excluded, the addition of lime to the water before filtration is suggested by Houston as a remedy. The effect of floods also in carrying pollution to collecting subsoil drains must likewise be considered, for it has been proved by experiments by Alba, Orlandi, and Rondelli, that on flooded ground the *Bacillus prodigiosus* will penetrate the soil at least 9 feet deep, and will reach subsoil collecting drains at that depth, and be conveyed into the storage reservoir.

Great Danger of Open Conduits for Conveyance of Drinking Water.—Very frequently the water supply is conveyed to the reservoir, and from it, to the distributing centre in open conduits, and these, if especial care is not taken, become polluted by the drainage of the district through which they pass. An open channel is likely to get filled with aquatic plants and weeds which add to the vegetable organic matter in the water, and at the same time are prone to render the channel a breeding place for mosquitoes. If an open channel has already been constructed it should be fenced in on both sides throughout its length and guarded against any pollution by drainage. It is almost impossible, however, to protect the conduit in a satisfactory manner. In the East the conduits are also likely to be used for ablution purposes or the washing of dirty clothes, and in this way the water becomes contaminated. It is not uncommon, also, for the banks of the conduit to be defiled, and the rain carries defilement into the water. These and other sources of contamination render an open conduit in the East and also in other parts of the Tropics a source of danger. The habits of the people have to be considered, and the only safe procedure is to have pipes or a covered conduit.

In South Africa weirs are frequently built across spruits or streamlets, damming up the water in order to form a reservoir at the site of the weir, or to direct the water to a dam in a more convenient situation. It is a supply that is liable to pollution from the absence

generally of any protective precautions. The custom of conveying the drinking water into the town in open furrows is one of the causes of the unusual prevalence of typhoid fever and dysentery among the civil population in South Africa. It often happens that the source of supply is absolutely pure, being obtained from a mountain stream or protected spring, but the water becomes contaminated before, or in the course of, its distribution, by being led into the town or village in an open furrow, which receives the drainage of the area of land through which it passes as well as the pollutions from cattle and domestic animals that drink from it. The furrow water consequently is the recipient of many impurities, inorganic and organic, and of vegetable and animal origin, before it is collected for domestic purposes. Natives have on occasion actually been caught emptying the contents of the excreta pails into the furrows.

The following is a description of one of these supplies taken from an official report, and it may be taken as a type which is to be found in many places. "From the dams the water is conveyed by open furrows along the sides of the streets, each erf (plot of land) having its own private furrow joining the public furrows. The dams are not fenced in, and in the dry season all the horses, cows, oxen, sheep and goats congregate in and near them. They are also the homes of countless water animals, especially frogs, crabs, &c., and yet these dams have not been cleaned out within the last ten years. Both of them are half silted up with sand and mud, so that they contain little water, and every year the amount gets less. The open furrows along the streets act also as drains or sewers; for on fall of rain all the refuse from the streets and back-yards is carried into them. The water from the dams is really intended for irrigation, but most of the poor people, white or black, habitually use the water for all domestic purposes, because it is so near at hand, running past their doors. This water

is without doubt clean at its source, for it comes from the high mountains round the village, but all the small streams coming down the mountains, and the large spruits above the weir are constantly contaminated by the various animals feeding on the commonage through which they flow. It is not unusual to find some dead animal in an advanced state of putrefaction lying in these streams. All sick animals seem to make instinctively for water, and often in the death agony they tumble into the water. The carcass remains there until pressure is brought on the street keeper by some disgusted citizen. However, this has been effectually put a stop to by the drying up of all the streams. In ordinary times most of the washing of the clothes is done in that which passes the village, but early this summer the stream ceased to flow and water could only be found in one or two holes in the bed of the stream; still the washing went on in them till the water was almost solid with soap and filth, and the smell could be felt for yards around."

The remedy for this state of things is filtration of the water which should be effected close to the dam, and the distribution of thus filtered water in pipes to the houses.

Rivers as a Source of Supply of Drinking Water.—The next source of supply is the river, which in the Tropics, as a rule, is in a less polluted condition than in Europe. This is because rivers in the Tropics are generally of larger volume, also because the foulest of the sewage seldom reaches them by drainage, except at flood time, when the excrement and sewage on the ground are swept into the river, and because there are very few, if any, manufactories on their banks. On the other hand, until recently rivers in India used to be fouled by dead bodies being thrown into them. This form of pollution is rapidly becoming a thing of the past. As drainage of towns is being introduced, unfortunately the most convenient outlet for the sewer often appears to be the river, without any attempt at sewage purification previous to

discharge, and consequently the former fortunate condition of affairs tends to disappear. When stating this condition to be fortunate, the seasons of dry weather and of heavy rains only are referred to; in the one case the sewage soaks into the soil and does not contaminate the river water, and in the other case the water is so abundant that the contamination is enormously diluted.

The self-purification of rivers is due less to chemical agencies and light than to the dilution of the pollution by the large volumes of filtered water which they receive from the underground waters on either side of them. Aided by the gradual subsidence of the organic matter to the bottom or sides of the river, where it undergoes bacterial disintegration, the swifter the current of the water the further down the river will the pollution be traceable.

The Water of Small and Shallow Rivers usually Dangerous.—The chief danger lies in the smaller rivers which may pass through thickly-populated localities, and which in the dry season are scarcely more than small rivulets, or a continuous line of puddles; or may dry up completely. At these times the river-beds become the receptacle of all kinds of pollution, and hence at the commencement of the rains the water in them contains a large amount of filth. The banks and the water itself are apt to be polluted by the inhabitants, when they come for water or to bathe. In South Africa after heavy rains the rivers may suddenly rise and become swollen and torrential, and almost as suddenly lower again, lessen in volume and swiftness, and become once more shallow streams. Cattle coming down to drink in these shallow streams often pollute the water by their excreta, and, in the case of animals in a debilitated state, not infrequently get stuck in the mud and die, thereby dangerously contaminating the water by their decomposing carcasses.

In obtaining water from a river it should be drawn from the main current and not from any back channel or stagnant water or shallow place near the bank. It may be necessary owing to the condition of the water near the

banks to draw the supply from a boat placed in mid-stream. For the supply of any permanent institution such as a barracks, jail, asylum, etc., a pipe with the inlet dipping into the water some distance from the bank, and connected with a pump to raise the water into a tank, is generally the most convenient arrangement. If river water is used for the water supply of a town care should be taken that for several miles above the intake the banks on both sides for at least 100 yards in width are protected by means of fences from access of animals, and regular inspections should be made to ascertain that nothing has fallen into the river, and that the fences are in order, and that no animals have succeeded in getting inside the fence ; also that the tributaries within the area are free of pollution of any kind. Often much attention is paid to the main streams but the smaller streams or tributaries are forgotten and neglected, and yet these are frequently contaminated with the drainage of houses on their banks or with other sources of pollution, which is only discovered by a careful inspection of such tributaries. The position of native villages that may be situated on the banks of the main stream or tributaries should always be noted in relation to the intake which is or is to be the source of supply of drinking water. No native village should be permitted on the banks of a river close to and above an intake. If rivers are used in the Tropics for drinking and general purposes, and especially if they are small and have little water in them, arrangements should be made by which a certain portion of the river is set apart for the supply of drinking water, a certain portion for bathing, another portion for washing, and another for the use of cattle. The part used for drinking purposes should, of course, always be highest up the stream, and that for washing clothes lowest down. During the war in South Africa this system was not always adhered to owing to the lack of sanitary medical officers and of any special sanitary organization. Apart from pollutions it was forgotten that the water of a pond, reservoir, river,

or lake, is always inferior and contains many more organisms when the sediment is stirred up than when the water is drawn off carefully. No river water whether in the Tropics or sub-Tropics can be drunk with safety unless it has been boiled or filtered, preferably boiled.

In the Tropics all drinking water, except that of large towns which has been efficiently filtered, ought to be boiled if possible, as the chances of pollution by pathogenic organisms of different kinds are so very great. Abyssinian wells, or wells of a type such as have been already described, if sunken on the banks of a river, often give by filtration from the river a very pure water supply. Certain native tribes in South Africa never drink water direct from a river, but scoop out a hole on the banks and drink the water which filters through the soil from the river into the hole or well.

The pollution to which a river may be subjected at the time of a great pilgrimage may be gathered from fig. 5, which represents the crowd of boats and people on a sacred stream in the suburbs of Calcutta on the occasion of an important festival. The stream became badly contaminated with dejecta from some cholera patients and by the body of a pilgrim who died of cholera. The result was a severe outbreak of virulent cholera among the pilgrims who drank of the water in the stream.

Tanks as a Source of Supply.—There is still another source of water supply which is used by many in the Tropics, and more especially in India, viz., ponds or tanks. They receive the rain which falls on the ground and which is conveyed to them by surface drainage. In many instances, as in Calcutta and in lower Bengal, where the land is low-lying, an immense number of tanks have been excavated, primarily for the purpose of supplying earth for raising the foundation of huts to be erected and for the mud-plastered walls of the huts. The tanks soon become a convenient storage supply of water for the inhabitants of the huts, while at the same time they

FIG. 5.—View of Tolly's Nullah and one of its Ghats on the morning of February 8. The Nullah is crowded with boats carrying pilgrims and with pilgrims bathing in the sacred stream.

become receptacles for the drainage of the neighbourhood and of the huts.

Other tanks are excavated in places where springs exist and are not wholly dependent on surface and subsoil water for their supply. The tanks get filled during the rainy season, but during the hot weather the water in them, unless supplemented by springs, becomes very low, and in some dries up altogether. Unless certain tanks

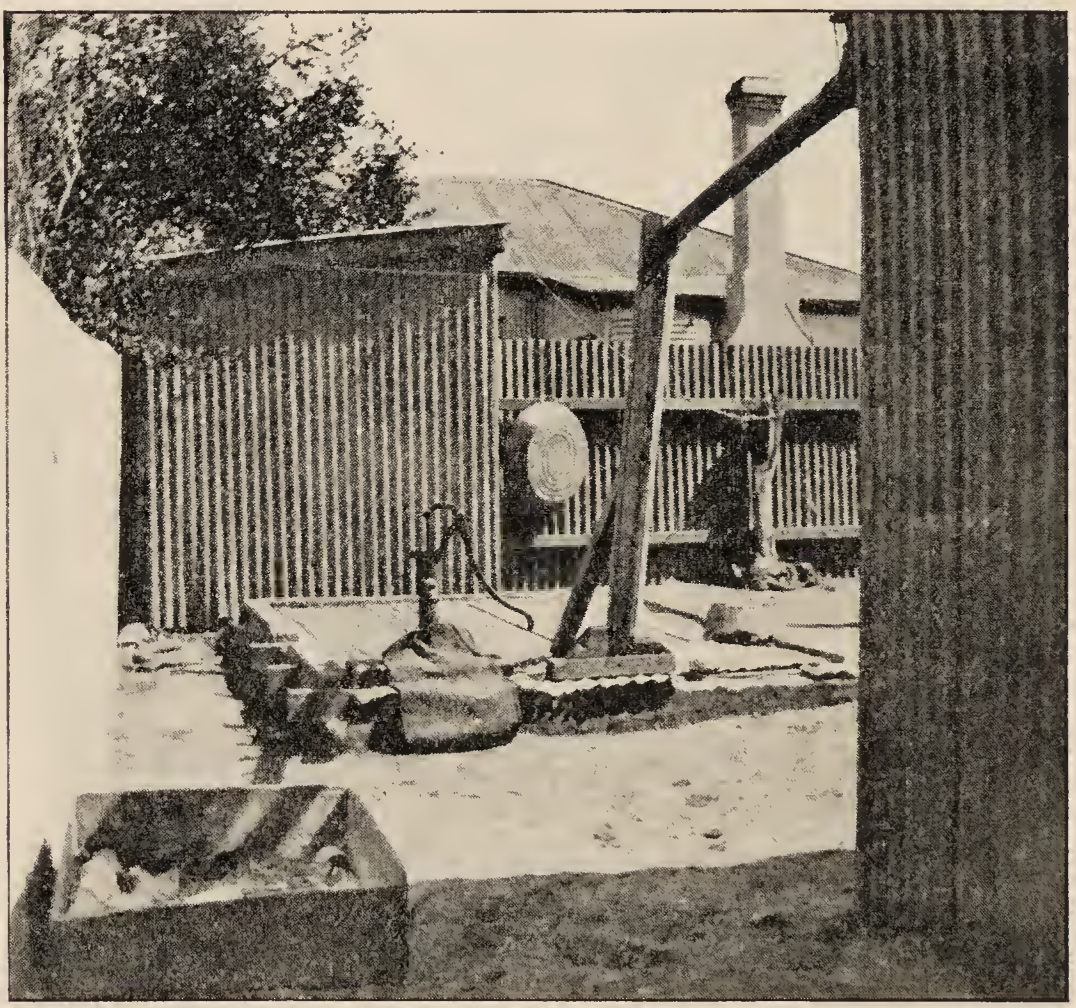


FIG. 6.—Underground Porous Water Tank, showing liability to contamination. Privy behind. Dirt box in front.

are specially reserved and precautions taken to prevent pollution the water in them is unfit for drinking.

Tank Water generally Subjected to much Pollution.—The pollution to which these tanks are subjected is frequently very great. Most of them are defiled by men and women bathing in them, by dirty clothes often soiled with the

excretions of the sick being washed in them, at times directly by human ordure, due to the practice of children and others defæcating on the bank of the tanks, and nearly always by the sulliage and drainage from the surrounding huts and houses (fig. 6).

The water in the tanks thus indiscriminately used and polluted, excepting during the *rainy season, varies in quality between diluted and concentrated sewage.* The range is shown in the following analyses. The first analysis is of water from a protected tank, in which no bathing, washing of clothes, or pollution by drainage is permitted; the next two are from tanks which are not protected, and the fourth is the water supplied to Calcutta, taken from the Hoogly, 20 miles above the town, filtered there, and conveyed to Calcutta in iron pipes, and distributed to the town.

	Chlorine	Ammonia		
		Free	Albuminoid	Total
Maidan tank...	20	0·06	0·09	0·15
Two tanks in native town	91	1·00	1·93	2·93
	318	32·00	35·08	67·08
Calcutta by direct water ...	4·9	0·00	...	0·02

The colour of the water of the tanks is often sufficient to condemn them. It is among the inhabitants dwelling around these tanks, and who drink the water or use it for domestic purposes, cleansing their utensils with it, or soaking their rice or other food-stuffs in it, that there are periodical outbursts of cholera.

The tanks are not only periodically infected with cholera germs in districts where cholera is endemic, but they form an excellent centre for all kinds of parasites. The ova of round worms, *Anchylostomum duodenale*, and *Dracunculus* or guinea-worm—the intermediate host of which is a cyclops—are to be found in Indian tank waters, and are brought there by the pollutions which they receive.

These dangers may be avoided by raising the banks of the tank so as to prevent surface drainage flowing into it; fencing the banks to prevent the inhabitants washing their clothes therein or polluting the water in any other way; sinking tube wells or ordinary wells at the side of the tank so that the waters from the tank supplying these wells shall first of all percolate through a certain amount of soil; or lifting the water direct from the tank or a well sunk in the tank, by means of a pump, to a covered tank which is supported on pillars, and from which the water is drawn through taps. It is useful to stock the tank with fish, which will keep down insects, larvæ of mosquitoes and crustacea. There are certain plants also which have been found effective in improving the water; among these is the Vallisneria, which gives off oxygen. For bathing and washing purposes there should be a separate tank.

The Transport of the Drinking Water to the house is an important matter in the Tropics.—Whatever the source of supply may be it is seldom that the water is brought into the house by means of pipes, as is the case in the larger towns of Europe. Even in large towns provided with modern waterworks it is only the few that can afford to introduce the water on to the premises of each house. A few of the better class houses may be so provided, but the vast majority are fortunate if there is a standpost in the street near the house. It is usually at the best a street distribution and not a house distribution. In India the bhistis, who are Mahommedan water carriers, employ the mashak for the conveyance of water to the house (fig. 7). The mashak is a leathern vessel made of goat or calf skin, and of the shape of the animal. It is filled from the neck which is afterwards closed by a thong, and it is then slung on the back of the bhisti. This mode of transport in a leathern vessel which can never be kept clean is one which is sure to contaminate the water however pure the source from which it is taken. If a bhisti lives in an infected house in which there is

cholera, typhoid fever, dysentery or other disease that can be conveyed by contaminated water, the mashak is likely to become infected and will spread it to those houses that are supplied with water from the infected mashak. This mode of transport should be discoun-

FIG. 7.—Water Carrier emptying his Mashak into household water vessel.

tenanced as much as possible, and if mashaks are used no water should be drunk from them until it is first boiled or filtered. Metal vessels should be used when possible, for they can be kept clean. The brass vessels

which are so prevalent in the East among Hindus and others (fig. 8) probably do more than prevent the water being contaminated by the vessel in transport; they may subserve to keep the water pure. The recent experiments on the effect of certain metals, such as copper and iron, on pathogenic organisms would point in that direction.

FIG. 8.—Water being carried from the river.

For the same reason water may be stored in metal, preferably bright copper, vessels.

Deposits in Pipes and Channels.—An important matter in connection with water supplies is the deposits in pipes, culverts, tunnels, and other channels conveying

potable water. These deposits not only lessen the carrying capacity of the pipe, but may affect the appearance of the water. The nature of the deposits have been studied by chemists and bacteriologists with the object of their prevention. Professor Campbell-Brown has given much attention to the subject, and the following is a *résumé* of his investigations.

The deposits are of three kinds:—

(1) Incrustations derived from the iron of the pipe on unprotected or imperfectly protected iron pipes. These incrustations are not due to acidity or alkalinity of the water, nor to organisms, but appear to be a solution of the iron of the pipe. They are only prevented by two or more coatings of pitch as an inner lining of the iron pipe.

(2) Deposits on the inner surface alike of iron pipes whether protected or unprotected, and of culverts, rock tunnels and other channels; the deposits depending in their nature on the composition of water and occurring over the whole of the surface covered by the water. They consist of a ferruginous slime formed by the growth of the germs and young forms of Chlamydothrix which attach themselves to and grow on the inner surface of the pipes and channels, and which appear first as specks, then as twisted threads with a gelatinous sheath. Iron oxide is deposited in the sheath and jelly of the organism. These deposits do not occur in alkaline waters, nor in waters containing carbonic acid. Acid waters producing this ferruginous slime should be treated by lime. The Clarke softening process has been found to produce good results. All such water should, moreover, be efficiently filtered.

(3) Accumulations of *débris* in inverts on hollows and irregularities in the water channels and in the *culs-de-sac*. These can be removed by rapid sluicing or by brushing.

The Diseases caused by Impure Water form a very large division of the diseases incidental to warm climates.— Besides the microbic and parasitic diseases which are

the chief dangers of drinking impure water, intestinal diseases of a diarrhœal and dysenteric character are produced by an excess of mineral impurities or of dissolved organic matter in the water, while poisoning may result from metallic impurities, the most common of which is lead.

Large quantities of magnesium, sodium and calcium salts, suspended clay, mica or schist, an excess of vegetable or animal matter, will produce intestinal disorders. Brackish water usually causes diarrhœa among those who use it for the first time. On the other hand, excess of the alkaline carbonates or of iron salts produces constipation. Drinking of water containing decomposing organic matter causes, when continued, a general low state of health with diarrhœa and attacks of fever. Any water containing a large number of bacteria will cause diarrhœa.

The most frequent cause for the prevalence of diarrhœa and muco-enteritis in the Army in the South African War was the drinking of unfiltered surface waters, especially those of rivers which contained a large amount of mineral and organic matters in suspension. The water of such rivers as the Orange, the Modder, the Vaal, the Eland, and the Crocodile was at times so loaded with suspended earthy matter as to be quite opaque, and when used as drinking water produced mechanical irritation of the bowels, developing later into muco-enteritis.

Diarrhœa and dysentery were also caused by drinking water containing decomposing animal matter, such as dead carcasses of horses and cattle in a state of putrefaction.

Among microbic diseases caused by contaminated water, cholera, typhoid fever, epidemic diarrhœa and dysentery are the chief.

Dysentery is generally due to contamination of the drinking water by excrementitious matter. An outbreak of dysentery occurred in 1905 in the 95th Russell Infantry, an Indian regiment, stationed on the outskirts of Singapore. The cause was traced by Colonel H. H. Johnston

to the pollution of the wells by the drainage of latrines that had been erected on higher ground. On the removal of the latrines the outbreak ceased. When pure water has been substituted for contaminated water in the Tropics dysentery has invariably decreased and in some cases disappeared. The two forms of dysentery, that which is due to the *Amœba coli*, and that due to the Shiga or the Flexner bacillus, appear to have water as their chief vehicle.

In the case of typhoid fever the water may become contaminated by urine as well as by intestinal discharges, both of which are now established to be infective in a typhoid fever patient.

Water contaminated with the discharges of a cholera patient has been proved with more certainty than that of other diseases to be the chief causal agent of cholera prevalence. Occasionally the disease is spread by milk, but it is usual for the infected milk to have been adulterated with contaminated water. Impure water serves as a vehicle for the ova and embryos of entozoa. Leeches may also gain access to the human body by means of the drinking water.

CHAPTER IV.

PURIFICATION OF WATER.

Purification of Water for Drinking Purposes Essential at all Times.—With the great risk of pollution of drinking water and the various diseases to which impure water gives rise in the Tropics, there is much reason to arrange for some method of purification. The methods vary in their kind, some depending on the use of chemicals, others on distillation, others on boiling, and others on filtration. Sometimes two or more are combined, and any adopted is generally dependent on the circumstances under which the water is required. For travellers, large bodies of coolies, or for an army they will differ from those employed for residents in a large town or village, or in institutions. In the one case portable, simple, and rapid methods are necessary, while in the other the installations are fixed and more elaborate in their nature. In the descriptions of the different methods of purification it will be easy to discern which are applicable to the one set of circumstances, and which to the other.

Chemical Methods.

Chemical methods come under two classes. One class employed for clarifying the water acts by precipitating the suspended matters it contains. The other class aims at the destruction of the organic matter and bacteria in the water.

Precipitation Methods.

No precipitation method sterilizes the water so far as pathogenic micro-organisms are concerned, and to that extent every such method is unsatisfactory, but while it does not kill the bacteria of disease it certainly lessens the chances of contracting disease in drinking water infected by such bacteria. The method does more than merely clarify the water from suspended matter, for in the process of clarification the water is indirectly purified by the bacteria becoming entangled in the precipitate, and carried down with the deposit. Hence, water that is unsafe without clarification can often be drunk with impunity after precipitation and decantation. Dr. Parkes quotes an instance of this. In 1868 the right wing of the 92nd Highlanders going up the river Indus suffered from diarrhœa owing to the muddiness of the river water. The left wing of the same regiment used the same water but previously treated with alum which forms a precipitate and carries down the suspended matter, with the result that it had no diarrhœa. The right wing then adopted the precipitation method with satisfactory results.

For precipitation, various vegetable juices containing tannin have been used. The tannin coagulates the organic matter and allows it to be deposited. The natives of India often use the clearing nut, which is the fruit of the *Strychnos potatorum*; they rub it on the inside of the water vessel. In other places tea and kino are favourite agents for this purpose. For travellers there is no better or safer drink than cold tea; it ensures that the water is boiled, the tea leaves act as a strainer of suspended matters, and the tannin coagulates and precipitates the organic matter, forming insoluble tannates. Chemical agents such as alum and lime are useful for precipitation purposes.

The addition to muddy and impure water of alum in the strength of 6 grains to the gallon is a process which has been long in use in the East for clearing and purify-

ing drinking water, and if 5 grains of lime are added after the alum the clarifying effect is rendered still better. On the addition of the alum a flocculent precipitate of aluminium hydrate forms, which absorbs the colouring matter in the water, entangles the solid matter in suspension, and gradually sinks to the bottom, leaving a clarified water above.

Alum is not only an excellent clarifier of water, but destroys water bacteria. Half a grain of alum to a gallon has been shown to reduce 8,100 micro-organisms in 1 c.c. of water to 80; while 2 grains, or even less, to a gallon has rendered the clear water after standing for twelve hours sterile, and left only a small number of microbes in the sediment. It is curious, however, that though alum appears to have this destructive power on water bacteria, it does not destroy in these or even greater strengths the typhoid or cholera organism. A mixture of alum, lime and sodic carbonate in powder makes up the anti-calcaire which is used in Maignen's process for softening and purifying water. In the case of hard waters various processes are used on a large scale for softening the water. There is Porter-Clarke process, Maignen's and Hewetson's. Every process of the kind contains lime which enters into combination with the CO_2 in the water and throws down a precipitate of calcic carbonate. Besides softening the water the process lessens the organic matter in the water by carrying it down in the deposits.

For large Water Supplies.—Iron is another agent used for clarifying water. *Anderson's process* consists in subjecting the water during its passage through revolving drums to the action of a continuous shower of metallic iron. The water afterwards passes over cascades to remove dissolved iron by oxidation, is then allowed to settle in tanks, and is finally filtered through sand. This process is in use at Antwerp, Worcester, &c., and it is found particularly useful for Nile water, which is clarified in a very short time after. It is not suitable for peaty waters.

The Mauritius Water Supply.—The Anderson process, combined with a special mode of aeration, has been found of use to get rid of that offensively fishy smell which sometimes arises after filtration of a water containing many forms of algæ. The water supply of the Mauritius is an instance where benefit has been derived from the employment of the Anderson process. There it is combined with a special method of oxidation, the usual cascades being found insufficient to purify the water.

The water supply of the Mauritius is obtained from the Mare aux Vacoas, which was originally a shallow morass surrounded by semi-tropical forest (fig. 9), and

FIG. 9.—The Lagoon and rushes, Mare aux Vacoas, Mauritius.

fed by numerous streams coming from a wooded district. This was enlarged and deepened by the construction of a dam (fig. 10), but the area was never cleared, the trees and scrub being immersed, and dying and decaying.

These bad conditions were improved by lowering the water level to the greatest extent possible compatible with the maintenance of the supply, clearing the banks of trees and vegetation down to the low water line, and 10 feet above high water. Cutting the voons or water-plants as close to the bottom as possible, and uprooting with a steam grab-dredger the roots and stumps of vacoas or screw-pines. Passages were formed for the principal

streams feeding the Mare, and all shallow areas of contaminated marshy water were banked off. These alterations rendered the water more filterable, but did not in the dry season get rid of the fishy smell of the water

FIG. 10.—The Overflow, Mare aux Vacoas, Mauritius.

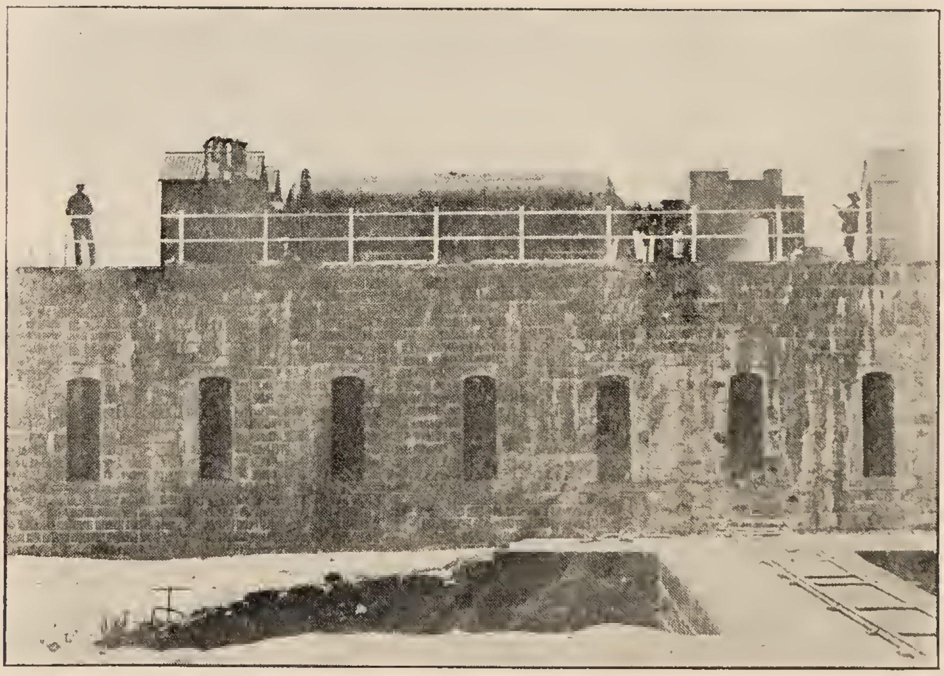


FIG. 11.—The Anderson apparatus, Mare aux Vacoas, Mauritius.

after filtration. This has, however, been removed, by first passing the water through Anderson's revolving purifier (fig. 11), and then into a specially devised aera-

tion apparatus or tray, perforated at the bottom in such a manner that the water passing through is exposed in droplets and not in a stream, to the action of the oxygen in the air (fig. 12). Finely divided in this way each droplet in falling through 4 to 6 feet of air becomes almost saturated with oxygen. In this way, first the ferrous compounds are oxygenated and the ferric hydroxide formed induces precipitation of a great part of the organic matter, and secondly, the saturation with oxygen facilitates the destruction of the residual organic matter during the passage of the water through the filters.[1] Sometimes, as in Singapore, a somewhat similar effect is obtained by intermittent filtration, which allows of ample time for the aeration of the filters.

The Ozone Method.

Sterilization by Ozone.—There is another method of purifying water on a large scale, which probably has a great future before it in the Tropics. This is the ozone process which, though of comparatively recent date, is now in use at Lille, Charlottenburg, Paderborn, Wiesbaden, Ginneken and other places. At Lille and Charlottenburg the water is conveyed to the top of a tower and then filters down through rough stones. The ozone having been prepared in a chamber near the tower is conveyed to it, is admitted at the bottom of the tower, and meets in its passage upwards the descending water. By the time the water reaches the bottom of the tower where it is received in tanks it is sterile—or contains very few bacteria. Experiments made at the works demonstrate that when the water is not sterile the bacteria undestroyed are generally *Bacillus subtilis*. The ozone is prepared by the passage of dried air through

---

[1] Mr. O. Chadwick, C.M.G., who introduced the system into the Mauritius, has kindly furnished me with the accompanying illustrations.

ozonizers supplied with electricity. At Ginneken in Holland, the water which is taken from the river Mark, and which is muddy and of a yellowish brown colour containing much organic matter, is first of all subjected to rough filtration through sand and gravel, before it is conveyed to the tower. The ozone meets the water in specially designed tubes, producing a strong agitation of water and the gas with a thorough mixture of the two. An average of 76·5 per cent. of the ozone is used. The purified water presents a striking contrast to the unpurified. Examination shows it to be colourless, well aerated, improved in chemical condition and practically sterile, while the crude water contains on an average, 6,000 colonies of bacteria per cc., the purified water, according to a recent examination, has about 50 per cent. of its samples sterile after two days culture, and 20 per cent. sterile after six days culture. Of the samples not thoroughly sterilized the maximum number of colonies developed was three at the end of three days, and twelve after six days. Most of the bacteria were *Bacillus subtilis*, *B. ramosus* and sometimes a liquifying bacillus; some pink colonies and air moulds were also found.

Ozone not only destroys water bacteria but has an even more rapid and destructive effect on pathogenic bacteria, such as those of cholera, typhoid fever and dysentery. *Bacilli coli* are also readily destroyed. Experiments by Van Ermengem, Calmette, Ohlmuller, Prall, Proskauer, and D'Ogier, establish the strong bactericidal properties of ozone in the purification of water and the paucity of bacteria able to resist the action of the gas. Those that resist are mostly sporing organisms, the most common of which is the *Bacillus subtilis*.

At Paderborn the Siemen's and Halske ozone apparatus[1] is used. The ozonizer consists of an iron box

---

[1] "Ueber Trinkwasserreinigung durch Ozon und Ozonwasserwerke." By Dr. G. Erlwein. Leipsig, 1904.

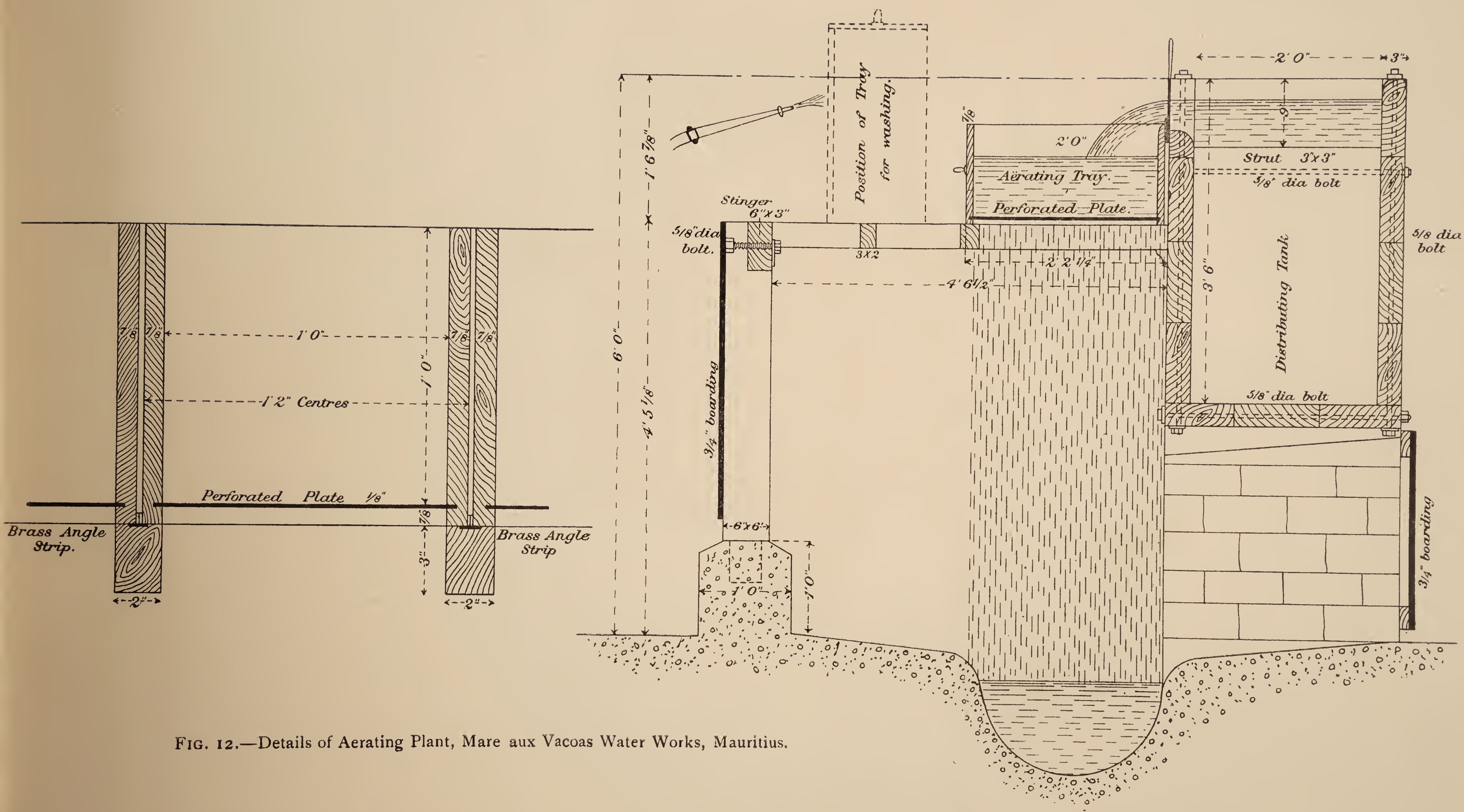


FIG. 12.—Details of Aerating Plant, Mare aux Vacoas Water Works, Mauritius.

(fig. 13, A, B, C), connected with the negative pole and divided into three compartments. Within the middle compartment are iron cylinders (D), resting on a glass insulator (F), connected with the positive pole and enclosed in glass cylinders (E) around which water cir-

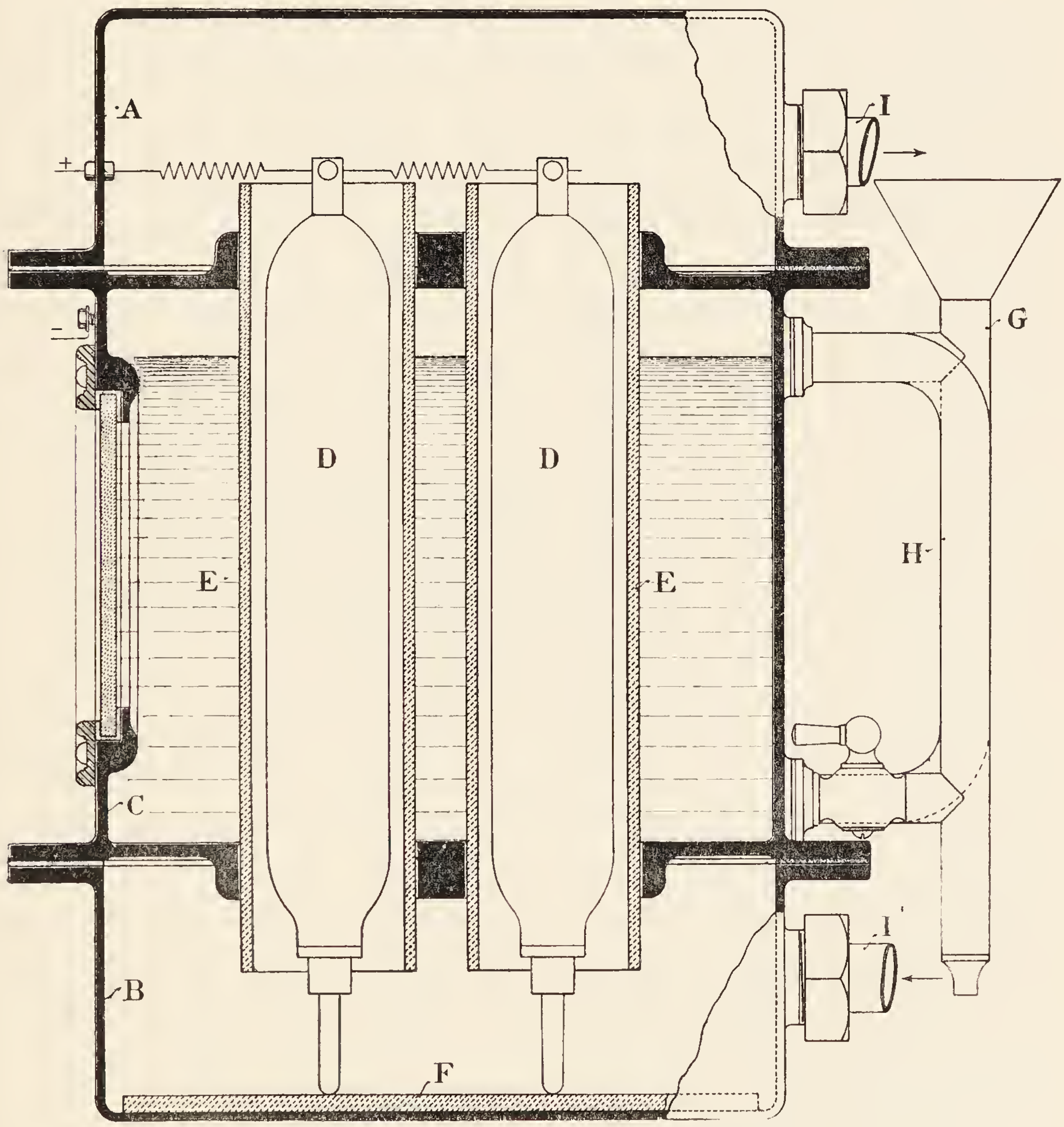


FIG. 13.—The Ozonizer of the Siemens and Halske apparatus.

culates in order to cool, entering by G and escaping by H. The air, admitted into the lower chamber by I′ is ozonized in its passage through the glass tubes, and is received as ozone in the upper chamber where, passing

through the outlet I, it is taken on to the sterilizers. The ozone passes through pipes to the bottom of the tower in which sterilization of the water takes place.

The sterilizers consist of a tower divided into four columns (fig. 14). The water is conveyed to the top of the tower, and by a pipe with four arms is distributed on to a sieve which allows it to fall as fine rain into the four separate columns of the tower, the lower portions of which are filled with a thick layer of flint, the stones of which are about a pigeon's egg in size, the water trickling over these flints comes in very intimate contact with the ascending ozone, and is thus sterilized. Through each section of tower 18 square meters in area, about 15 to 20 cubic meters of water pass in the hour, and requires 30 to 40 cubic meters of ozonized air per hour for its sterilization, each ozonizer with 1 horse power and 8,000 volts yields 13·5 to 27 grams of ozone in twenty-four hours, and sterilizes 26,400 gallons to 52,800 gallons per day. The ozonized water collected at the bottom of the tower passes down over cascades to get rid of any extra ozone that may be dissolved in it.

There are certain precautionary arrangements for the stoppage of flow of water to the towers should anything go wrong with any part of the works. The Wiesbaden ozonizing works are much on the same lines as those of Paderborn only on a larger scale. It is possible to sterilize 250 cubic meters in the hour. The apparatus is in duplicate each capable of sterilizing 125 cubic meters in the hour. The Wiesbaden water contains iron and comes from the sterilizers with a slightly yellow colour. This necessitates filtration after sterilization.

Siemens and Halske have constructed a transportable sterilizer consisting of two parts, viz., a petroleum driven motor and a wagon with complete sterilizing installation, dynamo, transformer, ozone apparatus, blower and sterilizing tower (fig. 15). It is capable of sterilizing 2 to 3 cubic meters per hour, *i.e.*, from 400 to 600 gallons an hour. It is this or some similar apparatus that will be

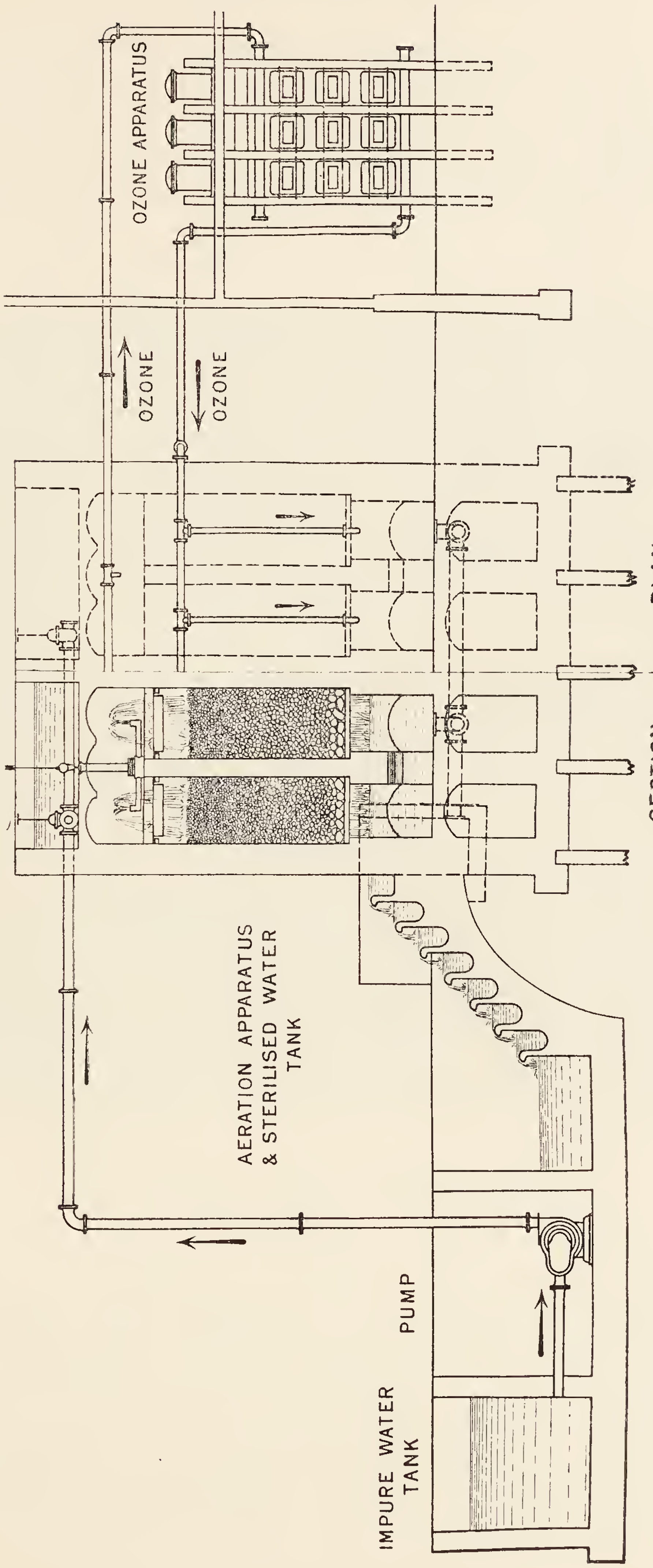


FIG. 14.—Diagrammatic plan of the Siemens-Halske plant for the sterilization of water by means of ozone.

found useful for providing sterile water to troops during war.[1]

The disinfection of wells and tanks has been for many years occasionally practised in India, but since Mr. Hankin directed attention to the excellent results which

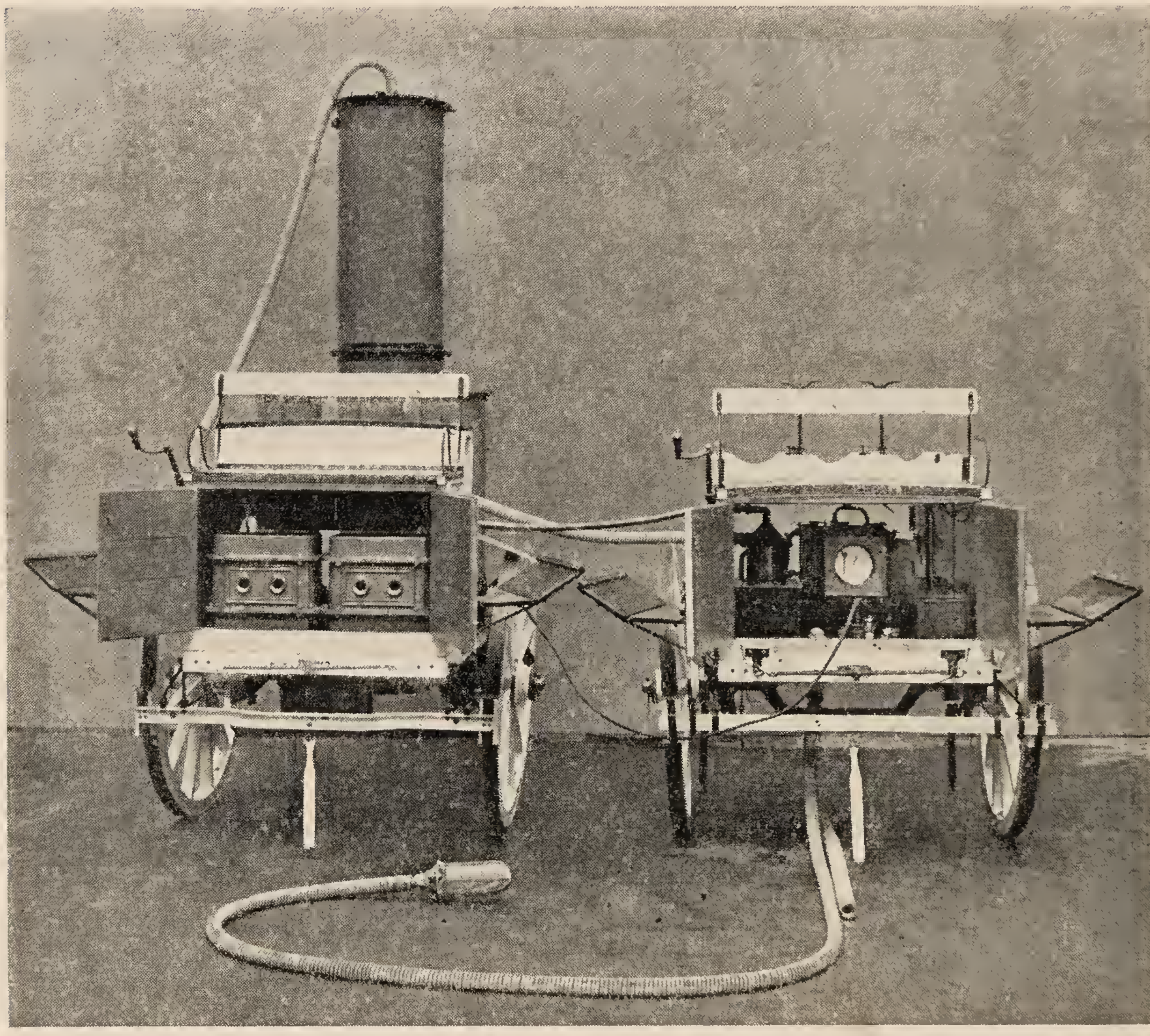


FIG. 15.—Portable apparatus for use in the field for sterilization of water by Ozone (Siemens-Halske System).

follow from the addition of permanganate of potash to cholera-infected wells the practice has been more systematic. Into an infected well a quantity of per-

[1] Messrs Siemens and Halske have kindly provided the illustrations used.

manganate of potash is added, which shall give an amount of 1 in 4,000 of the well water. If this quantity, owing to the large proportion of organic matter in the well, does not render the water pink for at least half an hour, more should be added until this standard is obtained. Roughly, 4 oz. for an ordinary well are sufficient. The permanganate should be first dissolved in a small vessel, which can then be let down into the well, sinking it to the bottom, then withdrawing it rapidly with the object of stirring up the water in the well and thoroughly mixing the permanganate. Some very good results have been reported of the efficacy of this method of treating infected wells. It is best to treat the well in the evening, so that by next morning all colour has disappeared. If the colour still remains, the addition of alum will soon render the water colourless. Lime to the amount of 1 oz. to the cubic foot of water has also been used for disinfecting purposes.

Permanganate of potassium or sodium is very useful for removing the odour from an offensively smelling water. To treat such waters add a few grains of permanganate of potash, and then heat gently and continue to add until a pink tinge remains for fifteen minutes.

Sterilization of Water by Chemicals.—Different methods of sterilization of water by means of chemicals and intended to be suitable for the use of travellers or of soldiers have been suggested. For this purpose bromine, chlorine and iodine have each been advocated. Any attempt at sterilization in this way should only be carried out with capsules or tablets containing definite quantities of bromine or chlorine to act on a litre of water, and the corresponding quantities of sulphite of sodium and carbonate of sodium to remove the colour, taste and odour which the water acquires by the first treatment. The most successful of the halogen group methods for sterilizing water is Vaillard's use of iodine. Three tablets are employed. The first contains iodate of soda and iodide of potassium with a blue colouring matter, the

second contains tartaric acid with a red colouring matter and the third contains hyposulphite of soda. The composition of the tablets is as follows :—

No. 1.	Blue tablet	Iodide of potassium	10 grams
		Iodate of sodium ...	1·56 ,,
		Methylene blue ...	a sufficiency.

Divide into 100 tablets each weighing 0·1156 gram.

No. 2.	Red tablet	Tartaric acid ...	10 grams
		Fuchsin	a sufficiency.

Divide into 100 tablets each weighing 0·1 gram.

No. 3. White tablet—Sodium hoposulphite.
Each contains 0·116 gram of sodium hyposulphite.

A blue and a red tablet are added to a litre of the water to be purified. By their solution free iodine is set free to the extent of 0·06 gram. Sterilization is effected in 10 to 15 minutes. At the end of this time a white tablet is added, the hyposulphite of soda, of which the tablet consists, neutralizing the free iodine by forming iodide of sodium. The water thus treated is odourless and free from any unpleasant taste. The method is one which requires unusual care and supervision and for this reason the circumstances for which it is adapted are not very numerous. It has been pointed out that the halogen group sterilize the water for bacteria but it is not established that they destroy parasites or their ova in impure water. Sterilization by chemicals is accordingly not a complete purification especially for water in the tropics which, as has been stated, is subject to pollution from sources likely to contaminate it with ova and with excess of mineral and vegetable matter. It is necessary that sterilization by chemical methods should be supplemented by filtration even when the water is clear and not muddy.

Liquid chlorine has recently been advocated by B. V. Nessfield, I.M.S., as an effective sterilizer of drinking water, especially for armies in the field. The liquid chlorine as used by Nessfield is stored in steel cylinders,

of such strength as to withstand the pressure resulting from a temperature of 200° F. The cylinder is provided with a tap, and in front of the tap a resistance valve which only permits, when the tap is full on, 1½ grams of chlorine to escape in two minutes. One and a-half grams of chlorine suffice for the sterilization of fifty gallons of water. A small-bore aluminium tube is attached to the nozzle, and this tube is perforated at the end with a single narrow opening. The method of use is as follows : a cask containing fifty gallons of water is rotated so as to give the water in it a circular motion, then the tubing attached to the cylinder containing the liquid chlorine is put into the cask, so that the end of the tube rests at the bottom of the cask where it is retained by a weight attached to it. The tap is then opened for two minutes. The liquid chlorine becomes gaseous in the tube so that in this way chlorine enters the water in almost a nascent condition. It is seen issuing from the tube in bubbles. Five minutes after the bubbling has ceased, a crushed tablet or tablets of sodium sulphite is thrown into the water. Thirty-six grains of sulphite of soda are required to neutralize one gram of chlorine in fifty gallons of water, so that in this case 54 grains are required.

$$H_2O + Cl_2 + Na_2SO_3 = Na_2SO_4 + 2\,HCl$$

If the water is not needed immediately, no sulphite of soda need be used to discharge the chlorine, for the gas itself will disappear in twenty-four hours.

$$Cl_2 + H_2O = 2\,HCl + O$$

The cost of the process is said to be one penny for each 500 gallons of water.

It appears from the experiments of Nessfield and F. N. Windsor, that in water subjected to free iodine for one minute, in the strength of one gram to 100 gallons, the organisms of cholera and of typhoid and the *Bacillus coli* are killed, but that sometimes owing to a larger quan-

tity of organic matter being present in the water double the quantity of iodine was necessary. The same variation was found also in regard to chlorine, which is nearly as effective as the iodine, but as there is a slight difference in the strengths, a slightly larger quantity of chlorine is required. Thus the cholera vibrio, the typhoid bacillus and the *Bacillus coli* were destroyed in one minute when the iodine was present in the water in the strength of one part in 260,000, while the typhoid bacillus was destroyed when the chlorine was of the strength of one in 350,000.

Other values have been given by other observers. The general germicidal value attaching to chlorine and iodine has been stated to be one in 17,000, but this is attributed by Nessfield and Winter to the use of broth cultures instead of water, the chlorine and iodine being absorbed by the organic matter of the broth.[1]

Copper Sulphate.—Recently sulphate or chloride of copper has been recommended for sterilization of water. The process however, has not reached that stage of certainty either as regards amount to be used or the harmlessness of the minute quantities of copper contained in the water as to bring it into general practice.

The process has been employed in America to clear lakes and ponds of their algæ, and also for purifying tributaries of rivers which supply drinking water; one part in a million is the usual strength employed. Even greater amounts have been used without any poisonous or injurious effects having been observed. On a small scale copper vessels have been used for the storing of suspicious water, or a strip of bright copper has been put into vessels storing water with the object of purification, because it appears that a twenty-four hours' storage in this way destroys *Bacillus typhosus* and *Bacillus coli.*

---

[1] A chemical process of sterilizing water for drinking purposes for use in the field and at home. By B. V. Nessfield, F.R.C.S., I.M.S. Notes and Bacteriological Report, by F. N. Windsor, M.B., I.M.S.—*Indian Medical Gazette*, July, August, December, 1905.

Boiling, or, as it has been called, the tea-kettle policy of treating water, is a method which has been employed both on a large and small scale in India and elsewhere. When properly done it destroys all living germs, and at the same time reduces hardness. The difficulty in hot climates with this method is cooling of the water afterwards. On a small scale this is often effected by putting the water into a clean earthenware vessel, which is suspended so that it may be well exposed to air currents. On a larger scale the cooling has been attempted by exposure of the pipes containing the hot water to the air currents. Neither of these methods of cooling can be said to have been very successful, and a simple and inexpensive system has still to be discovered. For large bodies of men engaged on large works, and for use in the army, Dr. Leigh Canney has devised an apparatus which boils water very rapidly, but it has the disadvantage of being unprovided with any cooling arrangements forming a part of the apparatus.

Sterilization by Heat.—Water has been sterilized under pressure so that none of the gases are lost, and attempts have been made to extract the heat from the sterilized water by the colder water that is passing to supply the sterilizer.

There are a number of sterilizers in the market having for their object the purification of drinking water. Such are the Forbes Water Sterilizer, the Maiche Automatic Water Sterilizer, and the Geneste Water Heat Sterilizer. The objections usually brought against sterilization of water by heat are that it is expensive on a large scale, and that if the water is hard there will gradually be a deposit in the pipes of the apparatus, which will interfere with efficiency and add to the cost. Doubtless both these objections will be ultimately overcome by the ingenuity of those interested in the process.

The principle of action of these sterilizers is shown in the diagram (fig. 16), in which the supply enters by the pipe 3, passes up to the heating chamber 5, heated by

a lamp 7, thence by the pipe 6 through 9 and 11, and is collected in a vessel 13. The heated water in 9 comes in close contact with the cold water entering through 4, from which it is separated by a thin partition 10, and in doing so is itself cooled and at the same time warms up the cold water.

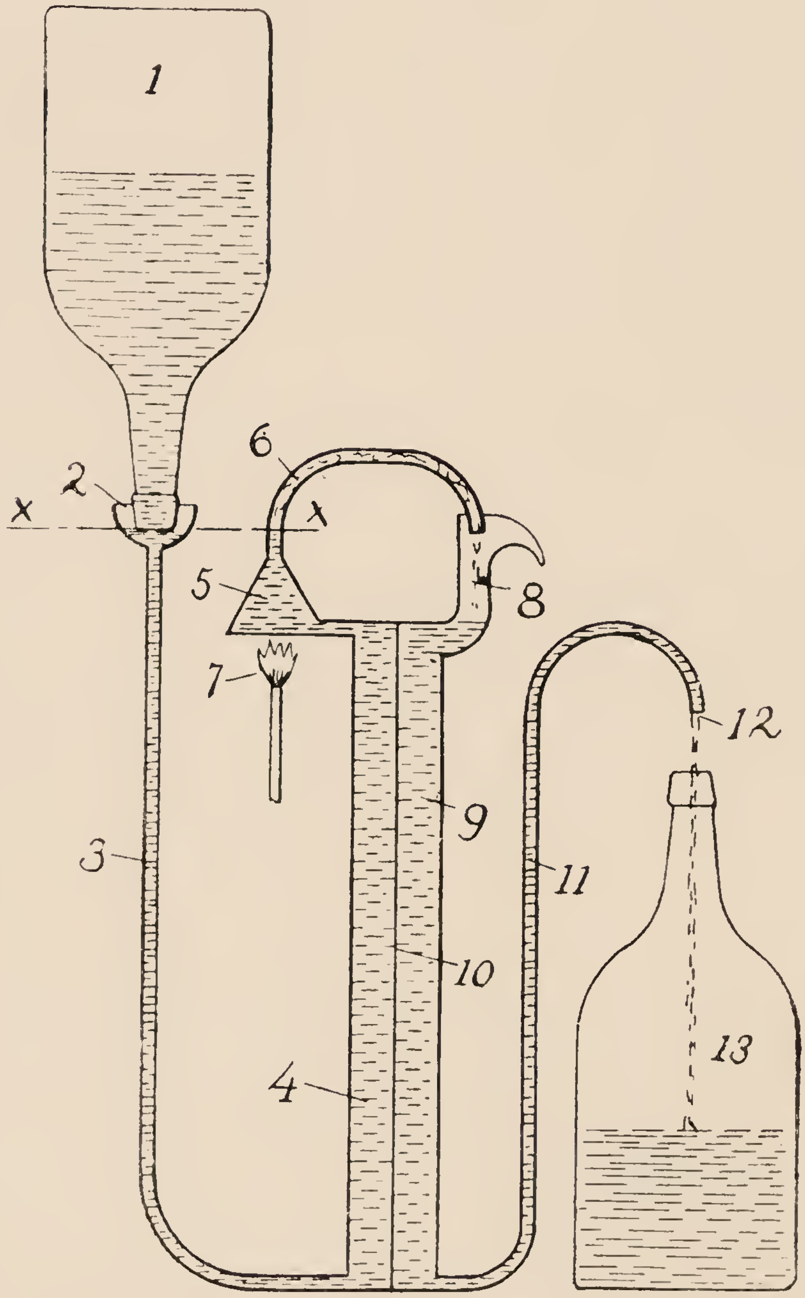


FIG. 16.—Apparatus for Sterilization of Water by Heat. Diagram of principle of operation.

The Waterhouse-Forbes Water Sterilizer is an American invention, and is well reported on by a Sanitary Board of Medical Officers after careful testing. The Board

recommended its issue for the use of troops in the field, finding that it is effective in purifying water heavily charged with the typhoid bacillus, the colon bacillus, or the *Bacillus prodigiosus*, all of them being destroyed by the process of sterilization.

The advantages claimed for the sterilizer are: (1) That the water passing through the sterilizer, although brought to the boiling point, is maintained at this temperature for so short a time as not to be deprived of its natural gases, and hence not rendered unacceptable to the taste. (2) That all living micro-organisms except a few spore-bearing bacteria are destroyed by the degree of heat attained during the passage of the water through the apparatus. The disadvantage of the escape of a few spore-forming bacteria through this apparatus is considered to be of no practical importance. (3) It furnishes an abundant supply of practically sterile water, and may be kept in action, if necessary, for the entire twenty-four hours without renewing the supply of oil in the reservoir. (4) The water having been slowly heated until it reaches temporarily the boiling point, is afterwards cooled to within $4\frac{1}{2}°$ F. of the water entering the apparatus. (5) Its durability and freedom from liability to breakage. (6) The facility with which the apparatus may be put together and entirely taken apart. (7) The facility with which the apparatus can be thoroughly cleansed.

Doubts have recently been thrown on the power to accomplish all that is claimed of this apparatus, and further experiments are being instituted to test its efficiency.

The Maiche Automatic Water Sterilizer is an apparatus somewhat on the same principle as the Waterhouse-Forbes Water Sterilizer, but not nearly so portable, and has gone out of use. It is useful, however, for hospitals and institutions in which it is desirable to purify the drinking and domestic water supply. A few of them were supplied in South Africa during the recent campaign.

Fig. 17 is a sketch of Maiche's Sterilizer, made use of in the Fort of Pietermaritzburg during the war, and which supplied 800 gallons a day of sterilized water to the mar-

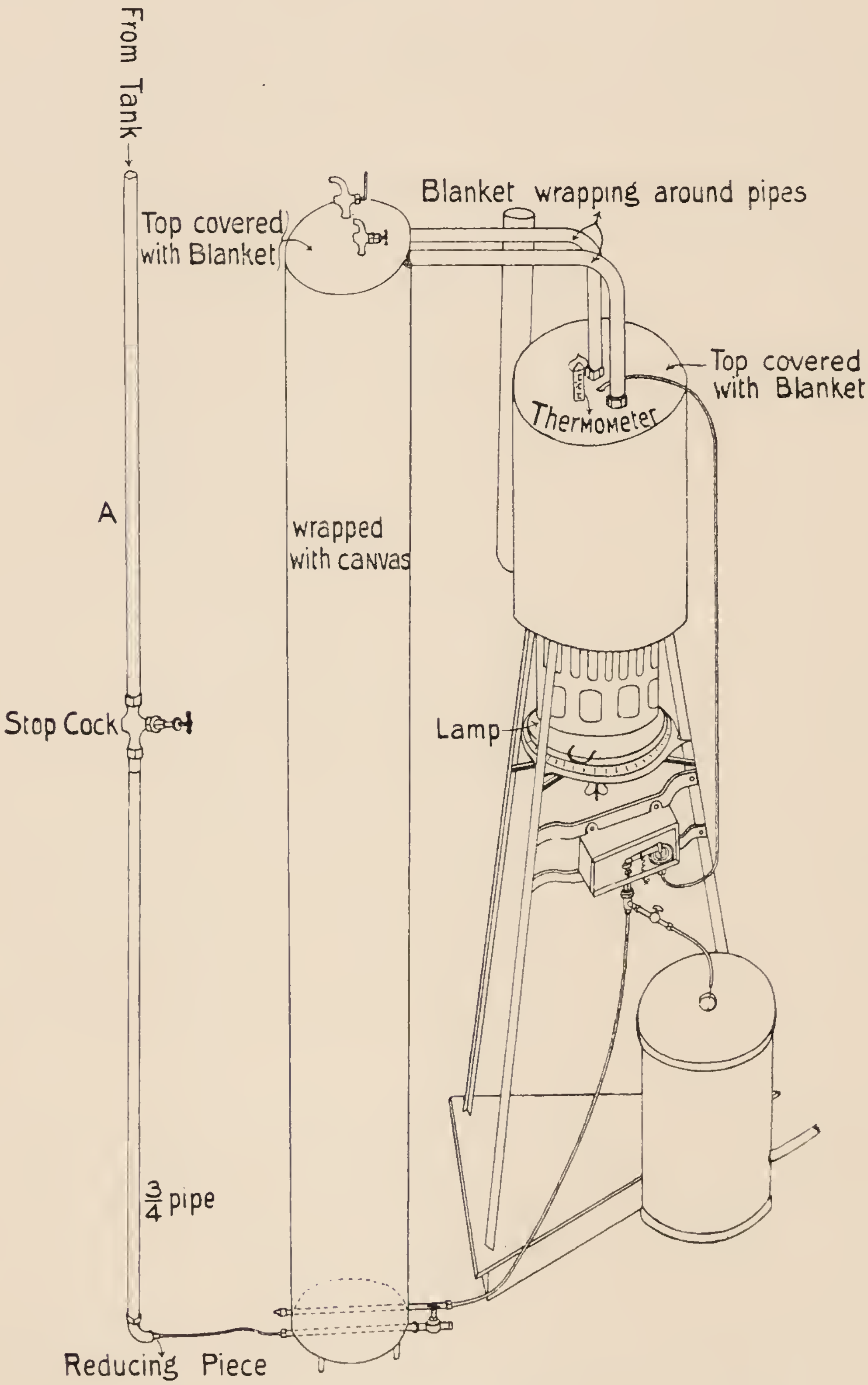


Fig. 17.—Sketch of Maiche "Sterilizer."

ried quarters. The sterilizer was placed in a small closed tower, which was formerly used for stores. On the roof of the tower was a water tank, supplied with unpurified

water, which was conveyed by a pipe through the roof to the cylinder of the sterilizer in the tower. The cylinder being longitudinally chambered, the water flowed through one of the chambers, and was then conveyed to the vessel in which the water was heated by a kerosene lamp. The heated water was then conducted back to the top of the cylinder, and in passing down in a small spiral pipe lost its heat to the incoming water, so that on leaving the cylinder and reaching the receiving tank the water was cool and fit for drinking. From the receiving tank in the tower the sterilized water was conveyed by a pipe to a 400-gallon tank situated at a convenient place in the fort, where it could be drawn off by taps as required. The initial cost of the sterilizer was £56, and in constant use it consumed five gallons of kerosene a week. The maintenance cost about 9d. a day for 800 to 1,000 gallons a day. The oil lamp required to be filled night and morning. The door was then locked, and the sterilizer left to work automatically. A part of the apparatus is a valve in front of the sterilizer, which regulates the flow according to the temperature attained ; the higher the temperature the quicker being the flow, and the lower the temperature the slower the flow. If the temperature falls below 212° the flow stops until the temperature rises. The valve requires very little attention, having in this case only been regulated once in six months.

Like the Waterhouse-Forbes Sterilizer, the Maiche retains the air of the water in solution, and accordingly the insipid taste that belongs to boiled water is wanting. Where neither of these apparatus is at hand, but where steam is available, water may be sterilized in iron tanks by conveying the steam by pipe to the tanks and then afterwards allowing the water to cool. This method can be used on a large scale, and is adapted to large works where there is plenty of steam.

In the *Griffiths' Sterilizer*, the water is not actually boiled but raised to a temperature of 175° F., which is probably

more than sufficient to destroy the vitality of non-sporing organisms like typhoid, dysentery, and cholera. It weighs 120 lbs. without its case, and was found in the tests to deliver 60 gallons of sterilized water per hour at 80° to 90° F. with a consumption of 1½ pints of oil.

Sterilization by Steam.—At Tintown, Ladysmith, where the water from the Klip river has the appearance at times of liquid mud, and where dysentery and enteric fever were attributed to the drinking of this water, a very successful method of clearing the water by alum and sterilizing it by steam heating was introduced to supply 2,700 persons, consisting of 2,000 Boers, 500 troops, 100 sick in hospital, and 100 followers with one gallon per head of sterilized water.

Six cylindrical corruguted iron tanks each capable of holding 1,350 gallons of water were erected on a wooden platform, a two inch pumping main supplied the water from the river, steam generated from the traction engines used for the electric light dynamos at night was, during the day employed, when required, for the water tanks. The steam was conveyed by a one inch steam pipe to the bottom of the tank, and introduced by jets by three branches of the pipe. The water was thus raised in each tank to 190° F. in about two hours, with 85 lbs. steam pressure in the boilers, after which 1¼ lbs. of alum were thrown into the water which precipitated the mud. The water was then allowed to cool, and was in thirty-six hours ready to be drawn off to the service main which was laid throughout the camp.

The routine adopted with the six tanks was half a day for cleaning, filling and sterilizing two tanks, one and a half days for cooling, and one day for emptying.

Filtration Methods.

Purification of water by filtration is adopted on a large scale for communities, and on a small scale for households and individuals. The ordinary filters for public water supplies are usually in water-tight basins of

10 or more ft. in depth, with sides built of masonry and bottoms cemented, or of brick cemented. In the floors are drains or channel ways for collection of the filtered water.

The filter itself is usually 5 or 6 ft. in depth, and made up, from the bottom, of broken stone or pebbles, covered by a layer of coarse gravel, on which is placed a layer of coarse sand, and finally a layer of fine sand. The object of this arrangement is to prevent the fine sand from being carried through into the drains, and to so regulate the flow that there shall not be any currents or streams. The water rests several feet deep in the filter, and should not be allowed to flow through the filter at a greater rate than four inches an hour (fig. 18).

The efficiency of the filter material depends on the fine particles of sand and on the thickness of the layers of fine sand, the coarse sand acting chiefly as a support to the layer of fine sand. The thicker the coarse sand layer is the more it displaces the filtering medium and affects its efficiency. In good filters the grains of sand whose dimensions are finer than a *millimetre* amount to 70 and 80 per cent. and the effective size of the sand grains is seldom 4 mm., generally being considerably less.

The filtration process is far from being a simple one, and has only recently been understood. At one time its action was thought to be merely mechanical, the sand separating out the suspended matter, and there can be no doubt that this is an important factor, the finer the sand and the thicker the layer of it, the more effective it is in straining the suspended matters in the water, and removing turbidity, sediment, and bacteria. Later, in addition to the screening properties, it was held that the oxygen in the filter acted on the organic matter, oxidizing it. Then it was discovered that the oxygen of the air has by itself little action on organic matter in water without the aid of microbes, and that the purifying effect of a filter is mainly due to a membranous layer of microbes on or near the surface of the filter. On the surface of a sand

filter there is a slimy deposit, composed of finely-divided clay with strong absorbent properties, and a gelatinous mass of intercepted bacilli and streptococci, micrococci, algæ and other bodies, and immediately below this film is a layer of nitrifying organisms.

FIG. 18.—Diagram of a section of a Sand Filter.

It is this slimy layer on the sand which is the important factor in removing micro-organisms and the organic

matter from the water. By the film the pathogenic micro-organisms are intercepted and destroyed, the organic matter is broken up into carbonic acid and ammonia, while by the nitrifying organisms the ammonia is resolved into nitrous and nitric acids.

The important points to be borne in mind with reference to sand filtration are that (1) there should be a thin layer of slime composed as above on the surface; (2) that this slime should not be disturbed during the process of filtration; and (3) that when the slime becomes too thick for the water to pass through it should be removed by scraping it off. If a filter be employed for too long a period without cleansing there is a gradual growth of the surface bacteria through the filter.

The filter bed requires cleansing at certain periods, otherwise the slimy layer would completely choke up the filter and render it impermeable. The period that elapses between the cleansing depends on the quality of the water and the fineness of the sand.

The method of cleansing is to remove a thin layer of sand half an inch in thickness, and disturb the upper part of the remainder of the sand by a fork, so as to expose it to the air, after which it is smoothed over. This process is repeated as occasion requires until the upper fine sand is reduced to a foot in thickness, after which the whole of the filter is taken up and cleansed.

The formation of the slimy layer on the filter may be a matter of only a few hours, or it may take twenty-four hours or even longer. The water at this time that passes through the filter is not free from impurities, and arrangements should be made to allow it to run to waste. The filter bed should be filled from the top, and the water should be allowed to stand in it at a depth of 3 ft. for at least twenty-four hours.

For efficient filtration the following conditions have been laid down by Koch: (1) The sand should not be less than a foot in thickness; (2) the rate of flow through the filter should not be greater than 100 mm., or 3·95 in.,

per hour, or not more than 200,000 gallons per acre per hour; for the more rapid the rate of flow through the filter the less is the efficiency of the filtration; (3) the quantity of microbes in the filtered water should not exceed 100 per cc. The mere provision of filters is not enough to secure good water; they must be well constructed, supervised, and frequently examined, especially in hot weather, in winter and in times of epidemics. Generally the rate of filtration should not exceed 2·57 million gallons per acre daily, but with clear water from lakes, ponds, and large storage reservoirs, which is comparatively pure and not subject to excessive algal growth, higher rates of filtration have been used with satisfactory results.

Care has to be taken that the fine film of bacteria, slimy algæ, and suspended matter is not broken. This may happen from the water being allowed to pass too rapidly through the filter, or from intense heat or cold on an exposed filter. Under these circumstances the filter is defective. In cold climates it is better for the filters to be covered over to prevent them from freezing; while in hot countries this is necessary in order that the water shall not be exposed too much to the sun, which renders the water warm, and at the same time favours the growth of algæ. The covering of the filters also excludes dust, which in some tropical countries is important. The storage tanks after the water is filtered should under every circumstance be covered over.

The very best sand filters cannot keep back all the micro-organisms in a water, but they possess the power of keeping back 98 to 99 per cent. of the bacteria. They have an enormous controlling power, as is seen by a comparison of the number of organisms in the water as discharged on the filters and the few that appear in the filtered water:

In Calcutta river water the germs were .	250,000 per cc.
In settling tank	20,000 ,, ,,
In settling tank with algæ	100,000 ,, ,,

After filtration :

In clean settling tank	15	per cc.
In settling tank with algæ	250	,, ,,

It will be seen that storage before filtration has also a very important effect on the reduction of micro-organisms which subside to the bottom. Bacteriological examination of water in a reservoir at different depths shows the number of microbes per cc. to be smallest near the surface, and that a gradual increase in number occurs as the depth increases.

There are two systems of sand filtration, the slow and the rapid, and in either system the filtration may be applied continuously or intermittently.

The slow sand filtration is the process which has been described, and is dependent on the gravitation of the water through the filter. There are conditions, however, in which the filtration through sand requires to be rapid, and for this purpose, the sand filters being usually limited in size, mechanical contrivances and pressure are brought into requisition. Mechanical filters are in greater use in America than elsewhere, and appear to be well suited for the muddy water derived from the rivers there. In the mechanical filter an artificial film of an intercepting nature is obtained by the addition of some substance which will form a fine deposit on the surface of the sand. Sulphate of alumina in the proportion of a half to two grains per gallon of water is most commonly employed. The coagulant, which forms a fine gelatinous precipitate on the surface of the filter, removes the colour as well as the suspended matter of the water, and as much as 98 to 99 per cent. of the bacteria. These filters are in covered reservoirs, and are placed under pressure usually by the admission of compressed air, and are cleaned by a reversed action of the filter, with sometimes the admission of steam. Their rate of filtration is generally about fifty times greater than that of the ordinary gravity filter (fig. 19).

Intermittent filtration is sometimes used, particularly in cases where the water contains much vegetable matter.

Storage of filtered water should be in covered reservoirs.

The testing of the efficiency of the filter by enumeration of the bacteria in the filtrate should be carried out

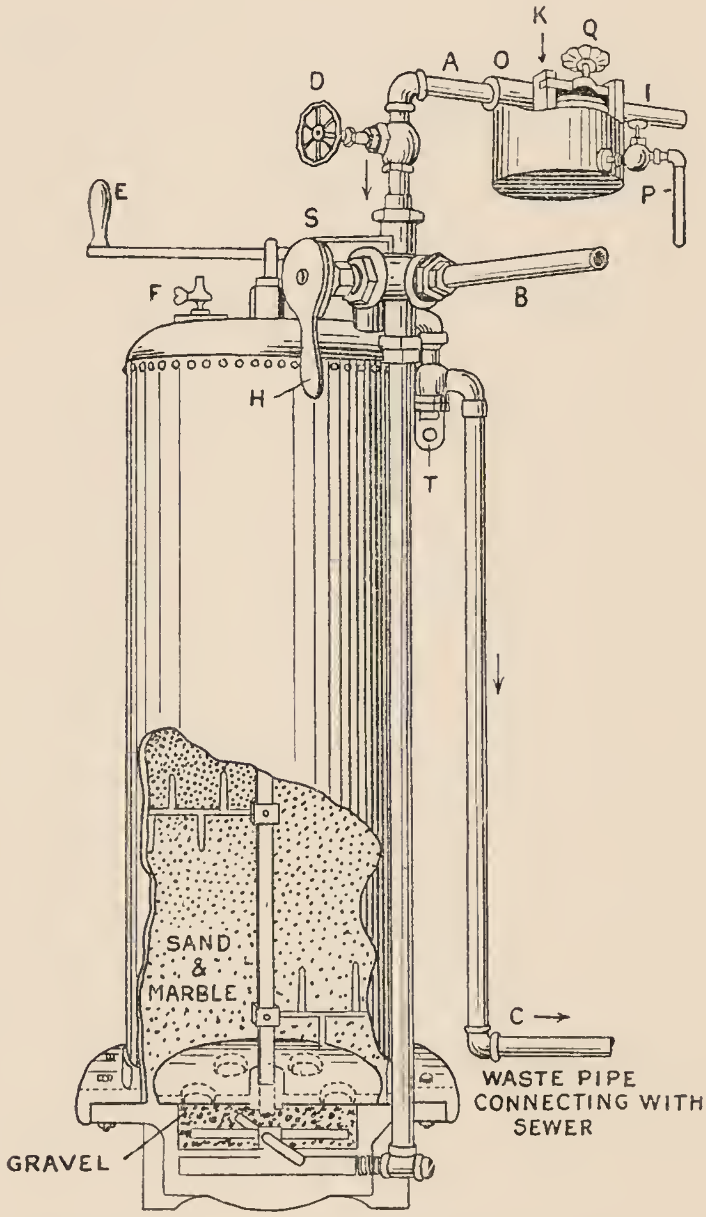


FIG. 19.—Diagram of a Mechanical Filter.

regularly and systematically. Each filter requires to be tested separately, so that there should always be arrangements by which the filtrate from each filter enters a separate conduit before passing to the common collecting well. The test should be applied at intervals of not less than once a week. If the test is not made at the water

works—which is by far the best arrangement—the samples of each filtrate require to be collected in sterilized flasks, and transported in ice to the laboratory where they should be examined at once. In the tropics nutrient agar is the only medium that can be used with facility. It is very difficult to deal with gelatine when the temperature in the laboratory is near blood heat and may be over 100° F. It means a constant supply of ice for the incubator if nutrient gelatine is employed. For a short period in the cold season a 10, 15 or 20 per cent. nutrient gelatine may be employed, according to the temperature. It has the advantage over the agar in showing the presence of liquifying organisms.

The method adopted is to melt the medium in a number of tubes, each of which contain 10 cc. of nutrient agar, by boiling in a water-bath. Use four tubes for each sample to be examined. When the agar has cooled to about 45° C., add to two of the tubes 0·1 cc. of the water, and to the other two tubes 1 cc. and pour into sterilized Petri dishes. This gives a duplicate plate for each quantity of water. Incubate in the inverted position for forty-eight hours at 37° C. and then count the number of colonies. No filtrate should contain more than 100 per cc. Systematic examination will soon give a good working standard and any deviation from this in the direction of a rise in the number of microbes per cc. should be immediately followed by an inspection and an examination of the particular filter that is at fault in order to discover the cause. In the meantime the filter should be put out of action if there is any considerable fluctuation indicating marked inefficiency. The importance of this is not always appreciated, though the neglect of it is attended with considerable risk. The mixing of imperfectly filtered water with that which has been properly filtered deteriorates the quality of the latter and may add to it dangerous micro-organisms. It is only a little removed from the pernicious practice which may occasionally be encountered of mixing good filtered water

with unfiltered in order to maintain the usual quantity delivered. Such a practice wherever existent cannot be too strongly condemned.

Domestic Filtration.—Filtration on a small scale for domestic purposes is now usually effected by two kinds of filters—the Pasteur-Chamberland and the Berkefeld. A few years ago there were on the market many kinds of filters, constructed of every variety of material; charcoal, asbestos, magnetic carbide, spongy iron, polarite, and silicated carbon were among the number. They have, however, gone out of fashion, having been found wanting in their action on bacteria. They do not sterilize the water or render it free from bacteria. It is because the Pasteur and Berkefeld possess this property that they have practically supplanted the others.

The Pasteur filtration is a purely empirical result, the uniform sterilizing efficiency of the tubes being due to certain details of composition and manipulation in manufacture. It appears to depend on a surface attraction which the material exercises on protoplasm of microscopic dimensions. Air passed through the dry tubes emerges sterilized, and organisms smaller than the pores of the filter are arrested. Purification does not at first depend on the formation of a layer of slime as in sand filtration, for sterilization begins immediately the tube is used, and occurs whatever may be the pressure of water. When steeped in water a Pasteur tube will not allow the passage of compressed air, and this circumstance enables a diagnostic test to be made of its bacterial soundness; or when a number of tubes communicate with a single receiver of the soundness of the whole filtering system, which for this purpose is immersed in water, so that a stream of bubbles will issue from a faulty point when compressed air is forced into the filtered water chamber.

The disadvantages of the filter are that it is not a gravitation filter but a pressure filter, requiring so much head of pressure before any considerable quantities can be obtained; and that in consequence of the ordinary river

water of the tropics being muddy or slimy, the filter becomes practically useless, for it rapidly gets a coating on its outside, which completely blocks up the filter and puts a stop to any water passing through, even under pressure. The same objections apply to the Berkefeld filter, with the additional one that it is more brittle than the Pasteur, and is not adapted for either rough transport or frequent cleansing. The filter candles need to be cleansed at least once a week by scrubbing and boiling.

The Berkefeld filter is on the same principle as the Pasteur-Chamberland. It consists of diatomaceous earth, made into a thick instead of a thin cylinder, and allows of water being filtered more rapidly. The same remarks as to disadvantages of the Pasteur-Chamberland apply as much to the Berkefeld.

The pressure difficulty is, as a rule, easily got over, for there are few places where a little ingenuity will not supply a sufficiency of pressure; and if not desirable to depend on this, there are numerous portable exhaust types in the market which can be adapted to every circumstance.

The readiness with which the filter candle—both Pasteur-Chamberland and Berkefeld—becomes blocked up is a much more serious affair, and leads sooner or later to the abandonment of its use. None of these kinds of filters will be of general utility in the tropics unless, as part and parcel of their structure, there is a rough filter attached, which shall first clarify the water and remove the slime.

The rapidity with which water can be filtered through a Berkefeld filter has brought it into favour for use in the Army, but as it needs to be boiled two or three times a week, there is great danger, even with careful handling, of breakage, owing to its fragile nature. A large supply of candles needs to be maintained for contingencies of this kind.

CHAPTER V.

EXAMINATION OF WATER.

Isolation of Disease Microbes from Water.—(*a*) *Koch's Comma bacillus.*—There is no difficulty in detecting the cholera microbe in water. The ordinary routine in Calcutta when any outbreak of cholera occurred was to discover the tank which contained the microbe. As several tanks were likely to be in the neighbourhood of the outbreak it was important to discover which was producing the disease. For this purpose several samples of water were taken from each tank in the vicinity of the outbreak and carried to the laboratory. There 3 or 4 cc. of each sample were put into sterilized wine-glasses, containing a solution of peptone of the strength of 2 per cent. with ·5 per cent. of chloride of sodium. The wine-glasses were covered with sterilized paper and put into the incubator at 37° C. Next day in those which contained cholera microbes there was a pellicle on the surface, which, on examination microscopically, was found to consist largely of comma bacilli. Sometimes commas were not noticeable, only short rods were to be seen. Under these circumstances tubes containing sloping nutrient agar were inoculated from the wine-glasses by zig-zag impressions, and on the next day characteristic commas could be detected. In this way the tank or other infected source of the outbreak could be detected; suspicion was thus converted into a certainty, and instead of having to carry out some general measures, which might not really touch the true source of infection, special measures were directed at once to

the source. In the case of tanks the precaution taken was to place a police guard over that proved to be contaminated, in order to prevent the inhabitants using its water either for domestic or other purposes until it could be emptied or cleansed. It was found that if a guard was placed over a tank for about three weeks, by the end of that time the comma bacilli had generally died out, and that usually it was safe to allow the water to be used again. The cholera vibrio does not stain by Gram's method and it gives an indol reaction, only requiring a few drops of nitrite-free sulphuric acid to be added to a twenty-four hours peptone water culture, when the cholera red quickly develops. Other tests, such as agglutination by a high grade cholera serum and bacteriolysis by Pfeiffer's test, are employed when it is a matter of doubt in a locality where cholera is neither endemic nor prevalent, but where cholera is known to exist, they are only a waste of time.

(*b*) *Eberth's Bacillus Typhosus.*—It is a very different matter to isolate the typhoid bacillus, and no absolutely satisfactory method has so far been discovered. The typhoid bacillus is much more difficult to isolate from a contaminated water, the reason being that other bacilli—particularly those of the colon group—multiply at a much more rapid rate, overgrow and conceal the typhoid bacilli.

Two methods may be employed with the object of endeavouring to isolate the typhoid bacillus from a suspected water: one is Hoffman and Ficker's[1] method, the other is Willson's.[2]

Hoffman and Ficker's method is dependent on the power which Roth discovered of caffeine in a nutrient medium favouring the growth of *B. typhosus* while checking or retarding the rapid development of *B. coli*. It consists first in adding to the suspected water to be

---

[1] *Hygienishe Rundschau*, xiv., pp. 1-7, 1904.

[2] *The Journal of Hygiene*, vol. v., pp. 429-443, 1905.

examined, nutrose 1 per cent., caffeine 0·5 per cent., and crystal violet ·001 per cent. This is done by adding to a litre of the suspected water 10 grams of nutrose, 5 grams of caffeine, and ·01 gram of crystal violet. The mixture is then incubated at 37° C. for not more than twelve or thirteen hours. At the end of this time the micro-organisms which have grown are isolated by plating on solid media, preferably Drigalski Conradi agar, or Loeffler's malachite green agar.

Willson's method makes use of the precipitating effect of alum on water. The precipitate entangles and carries down the bacilli which can then be isolated from the precipitate by plating after centrifugalization on Drigalski Conradi agar, or Loeffler's malachite green agar.

For the process a stock solution of alum in distilled water of the strength of 10 grams to 100 cc. is prepared. Then to a measured quantity of the suspected water there is added so much of the solution of alum as to be in the proportion of 0·5 gram of alum to the litre of water. Thus to a litre of the water is added 5 cc. of the alum solution. If the water is acid sufficient sodium carbonate solution must be added to render it neutral. In a few minutes when the precipitate has completely formed, the vessel is shaken to evenly distribute its contents and successive quantities of the water are centrifugalized each for fifteen minutes until the whole of the water has been dealt with. The clear water in the centrifugal tubes is poured off leaving about 0·5 to 1 cc. of fluid behind. The precipitate at the bottom of the tubes is well stirred and the contents are taken up in a sterile pipette and spread over several Drigalski Conradi plates which are incubated at 42° C. for twenty-four or forty-eight hours, or on plates of Loeffler's malachite green agar.

Klein's method of isolation of Bacillus typhosus in water. Water and B. typhosus. Enrichment Method.—B. typhosus in water is easier to isolate than in milk, because there are fewer bacteria and water may be concentrated by

filtering through a porcelain filter, and collecting the particulate matter on the surface of the candle. Drigalski plates are capable of demonstrating *B. typhosus* in the filter brushing, if *B. typhosus* is present in fair numbers in the original water. Unfortunately, this is rarely if ever so; in most instances for obvious reasons a typhoid water supply contains *B. typhosus* in extremely small numbers—hence negative results are obtained in most instances. [In using filter brushing about 25 to 30 per cent. of bacteria are lost.] Therefore enrichment of *B. typhosus* in the water is of great importance. This may be done as follows: To each 1,000 cc. of the water in question add: 10 grams of Liebig; 10 grams of peptone (pure); $\frac{5}{8}$ gram of sodium taurocholate (= 0·65 grains); 66·6 cc. or 71·5 cc. of 1 per cent. solution of malachite green; the former would make malachite green 1 in 1,600, the latter 1 in 1,500. Incubate at 37° C. from twenty-four to forty-eight hours, and then make Drigalski plates. In this way large volumes of the water without any loss by filtration can be converted directly into a culture medium suitable for the multiplication of the *B. typhosus*.

The solid medium most usually employed for the isolation of typhoid bacilli is the Drigalski Conradi agar. Its constituents are nutrose, lactose, litmus, and agar with 0·001 per cent. of crystal violet. The plates prepared with this medium should be dried for several hours in the incubator. They are then ready for use to differentiate bacilli of the colon group from *B. typhosus*. If inoculated with water containing *B. coli* and *B. typhosus* and placed in the incubator at a temperature of 42° C., in twenty-four hours a difference will be observed in the growing colonies which is distinguishable by the naked eye. The typhoid colonies will appear as small bluish white growths which do not change the violet colour of the medium around them, while the coli colonies will be a glistening white by reflected light and a bright red by transmitted light. These differences in colour will be

more pronounced after forty-eight hours. The medium round the coli colonies acquires a red colour, while that round the typhoid remains unaltered.

The colour test is only a sorting process and one which though it separates the *B. coli* from the *B. typhosus* by no means separates the *B. typhosus* from other micro-organisms that may grow on the Drigalski Conradi agar, at the high temperature of 42° C., and that like the *B. typhosus* do not produce an acid reaction. Colonies of the *B. non-liquifaciens*, *B. pyocyaneus*, streptococci, vibrios and members of the *subtilis* and *mesentericus* groups grow on this medium and some may have the appearance of those of *B. typhosus*. It is, therefore, necessary to subject all colonies which resemble those of *B. typhosus* to the ordinary tests which determine their genuineness or otherwise. Their microscopical, chemical, cultural, biological, and pathogenic characters are therefore investigated as follows:—

(*a*) *Microscopically* examined they are motile. They do not stain by Gram's method.

(*b*) *Chemically* they give no indol reaction in broth or peptone water culture seven days old at 37° C.

(*c*) The colonies on the *surface* of gelatine plates exhibit a leaf-like expansion when viewed microscopically.

(1) In *gelatine shake*—no gas.

(2) In *broth* "shimmering" turbidity, no pellicle.

(3) In *potato* scanty, colourless growth. If the potato has an alkaline reaction the growth may be yellowish.

(4) In *litmus milk* slight acidity—no coagulation.

(5) In *litmus glucose peptone water* acidity—no gas formation.

(6) In *litmus lactose peptone water*, no acidity—no gas formation.

(*d*) Specific biological reactions:—

(1) *Agglutination.*—The bacillus should be agglutinated by the serum of a typhoid patient in 1 to 50 dilution or by the serum of an animal immunized with a known typhoid strain in much higher dilutions such as 1—1000.

(2) *Pfeiffer's Test.*—The bacillus when mixed with the serum of an immune animal and injected into the peritoneal cavity of a guinea-pig should show the phenomena of bacteriolysis, or the same should be exhibited *in vitro* when the bacillus is mixed with the serum of an immune animal and with the fresh serum of an animal not immune.

(3) *Pathogenic Test.*—The bacillus should be pathogenic to rabbits and guinea-pigs.

The conclusion has to be based on the combined results and not on one or two tests.

Isolation of Bacilli Coli.—The importance of *B. coli* in drinking water cannot be emphasized too much as indicative of sewage pollution, especially when associated with streptococci. Large numbers of *B. coli* in water render it unfit for potable purposes, and there should be no hesitation in condemning such a water. The presence of *B. coli* in small numbers should raise suspicion as to the purity, and be followed by a careful inspection of the supply from its source downwards to ascertain the kind of contamination to which the impurity is due. This inspection is necessary in order to determine whether the sewage pollution is from animal or human excreta. Savage, Daniels, and Houston have shown that *B. coli* are found in upland waters even from sources where excretal pollutions from human beings was out of the question. The source of the bacilli in these cases is from fish and the lower animals and not from man.

The method here recommended for the detection of the *B. coli* is that approved of by a committee of the Royal Institute of Public Health, 1904. It is the bile salt method of MacConkey, the medium consisting of bile salt lactose peptone water combined with the isolation of the coliform bacilli and the determination of their characters. The sodium taurocholate prevents the growth of large numbers of water bacteria.

The suspected water is added to the culture medium in the proportion of equal volumes of water and of culture

medium, but when in large quantities of 10 cc., 25 cc., or 50 cc., the culture medium should be twice its ordinary strength. No opinion should be formed without examining at least 50 cc. of the suspected water.

The process usually consists in taking in duplicate two sterile tubes or flasks, one set containing 25 cc., the other 10 cc. of bile salt lactose peptone water of double strength. Also in duplicate a tube containing 1 cc. of the bile salt solution of ordinary strength. To each of the flasks containing 25 cc. and 10 cc. of the bile salt solution add 25 cc. and 10 cc. respectively of the suspected water, and into each of the tubes containing 1 cc. add 1 cc. of the water. Incubate at 42° C. for forty-eight hours. If the medium turns red, due to acidity, and gas is formed, collected in a Durham fermentation tube within the flask in any of these, there is reason to suspect the presence of *B. coli*, which should be isolated by transferring a loopful of the culture into 10 cc. of sterile water, and of this dilution transferring ·5 cc. on to plates of litmus lactose agar, or Drigalski Conradi agar. In the event of red colonies characteristic of *B. coli* growing on these media, they should be further tested to ascertain if they belong to the group of excretal coli. If the *B. coli* be of this kind, microscopical examination shows them to be motile, though this characteristic may be occasionally wanting. Inoculated into litmus milk, and incubated at 37° C., permanent acidity is produced, and the milk is curdled within seven days. Inoculated into lactose and glucose litmus peptone waters acidity and gas are produced and cultures of five to seven days in peptone water give the indol action.

Houston uses the word "flaginac" to express the sub-cultural tests which he uses. Thus—

fl indicates greenish fluorescence in neutral red broth cultures.
ag ,, acid and gas in lactose peptone cultures.
in ,, indol formation in broth cultures.
ac ,, acidity and clotting of litmus milk.

The word "flaginac" thus indicates that a microbe is indistinguishable, as regards the tests employed, from the typical *B. coli* of the human intestine. When the letters are placed in brackets an incomplete reaction is indicated. The absence of a character is expressed by the omission of the letters chosen to indicate that attribute.

The interpretation to be placed on the presence of *B. coli* in water will depend on the kind of water examined. Deep well and spring waters should be looked on with suspicion if typical *B. coli* are isolated from 100 cc. or less, whereas surface water need not be looked on with suspicion unless *B. coli* are isolated from 10 cc. of the water or less. If from 1 cc. or less the water is obviously polluted. The kind of pollution, *i.e.*, whether due to the excreta of man or animals, and the source of pollution, have to be determined by inspection and a careful examination of the supply. The results of the bacteriological examination only indicate that pollution exists of an excretal nature. In the search for that pollution, particularly in a surface water, bacteriological examination of the water for *B. coli* in and along the different feeders and streams, will materially assist and give precision and definiteness to the sanitary inspection. In a sanitary inspection of this kind enumeration of the colonies on nutrient agar plates, inoculated with 1 cc. or 0·5 cc. of the water at different places, and incubated for forty-eight hours at 37° C., often gives valuable comparative results which considerably assist in forming an opinion. It should, however, be done supplementary to the examination for *B. coli*, which is the important test.

Composition and preparation of culture media:—

(1) MacConkey's medium.

Sodium taurochlorate ...	5 grams.
Lactose	5 ,,
Peptone	20 ,,
Water	100 cc.

Heat until solids dissolve, filter and then add neutral litmus solution to give a distinct colour.

(2) Drigalski-Conradi medium.

A. 15 grams of Lemco			water, 1 litre.
10	,,	nutrose	
10	,,	peptone	
5	,,	salt	

Boil for one hour, then filter; add $2\frac{1}{2}$ per cent. agar, boil for three hours, and filter.

B. 100 cc. Kubel-Tiemann's litmus solution
15 grams lactose
Boil for ten minutes.

Add B to A. Add to the mixture 10 cc. of a ·01 per cent. crystal violet, then add 2 cc. of a 10 per cent. solution of sodium carbonate.

(3) Löffler's malachite green agar.

Nutrient agar with the addition, *at the time of using*, of malachite green (No. 1, Höchst). The dye should be added in solution to the melted agar in the proportion of about 1 in 6,000, *e.g.*, 0·1 cc. of a 1·6 per cent. solution to a 10 cc. tube of agar.

CHAPTER VI.

FOOD SUPPLY.

The Principles of Diet and the Construction of Dietaries.

The Alimentary Principles the same in the Tropics as elsewhere.—Next to the quality of water, that of food requires attention. From a general public health point of view, care has to be taken that the food is not inferior in quality, nor is a vehicle of disease. In large institutions additional care has to be taken that the diet is sufficient and not defective in its alimentary constituents. Defective diet is not an unfrequent source of ill-health in jails, lunatic asylums, and other institutions where large numbers have to be provided for. It can be readily detected by regular and periodical weighing of the inmates. Loss of weight, affecting an unusual proportion of these inmates, or a general tendency to scurvy with ulceration of the gums, or an undue admission of patients into hospital with dysentery of a scorbutic type, are indications of a deficient or defective diet, the cause of which should be inquired into and removed. To ascertain if there is any defect connected with the amount or relative proportion of the constituents of the diet, it is necessary to be conversant with the general principles of diet. These principles are the same everywhere, although the food-stuffs may differ greatly. The simple and for the most part vegetable diet of the indigenous inhabitants of the Tropics contain the same nutrient principles as the more complex and varied admixtures of animal and vegetable food-stuffs which form the ordinary diet of races living in colder climates with a modern civilization.

Tissue formers and energy and heat producers are needed for nourishment in the Tropics as in cold countries, and for this purpose proteids, carbohydrates, fats or oil, water and salts, have to be provided. These nutrients are classed as follows :—

Tissue Formers.	Energy and Heat Producers.
Proteids.	Proteids.
Mineral matter.	Carbohydrates.
Water.	Fats.

The proteids belong to both classes by reason of their composition, which consists of 16 per cent. of nitrogen, 52 per cent. carbon, 7 per cent. hydrogen, 23 per cent. oxygen, and ·5 to 2·0 per cent. sulphur. Their main function is to provide nitrogen in a suitable combination to the cells in order to build up and repair the tissues. In the process of metabolism they are the constituents of the food engaged in the growth and renewal of the tissues of the body. The nitrogen in them is essential to make good the loss in the tissues. No other constituent can supply that nitrogen, and in consequence it is impossible to maintain life without proteids. Owing to the carbon which proteids contain they also take a part in providing energy and heat, but in a very subordinate position compared with that performed by the carbohydrates and fats. When carbohydrates are not available it is possible, however, for proteids to supply the necessary energy and heat; in fact, some races, such as the Indians of the Pampas, live wholly on proteids, water, and salts.

The carbohydrates and fats contain carbon, hydrogen, and oxygen, but no nitrogen. The carbohydrates represented by the starches and sugars consists of 44·4 per cent. carbon, 6·2 per cent. hydrogen, and 49·4 per cent. oxygen. Fats differ from carbohydrates in containing a much larger percentage of carbon, having on an average 76·5 per cent. of carbon, 11·9 per cent. of hydrogen, and 11·5 per cent. of oxygen. They supply the heat and energy requisite for the maintenance of the temperature

of the body, and for the performance of the internal and external work of the body as involved in respiration, circulation, digestion, locomotion and other work.

Fats reckoned as starch produce nearly two and half times the amount of heat and energy as that of carbohydrates, but owing to their smaller proportion of oxygen are less easily oxidized.

Water is necessary as a food for the tissues into whose structures it enters so largely, forming about two-thirds of the weight of the body. It is also a carrier of the nutrient material and waste products. The salts or mineral matter, as combinations of lime, magnesia, potash, soda and iron, with chlorine, phosphoric acid, carbonic acid and sulphuric acid, and of which chloride of sodium, phosphates of lime, potash and magnesia, and traces of iron are the chief, enter into the constituent parts of the body, and form essential elements in the composition of tissues and secretions. The chlorides keep the proteids in solution; the phosphates of lime, potash and magnesia are needed for the formation of bone; the potash-salts for the blood-cells and muscular fibres; the soda-salts for the intercellular fluid bathing the tissues; and the iron-salts for the red corpuscles and for the colouring matter in the muscles.

In addition to the foods there are food adjuncts, which are not essential constituents of a diet, but which give it flavour and variety, increase the flow of the digestive secretions, and not unfrequently exert an influence on the nervous system. Under this heading are alcohol in fermented and distilled liquors; volatile or essential oils and other aromatic compounds as contained in condiments such as garlic, turmeric and pepper, and in spices such as ginger and cloves; also vegetable acids and alkaloids such as theine and caffeine in tea and coffee.

The Nutritive Principles supplied by the Natural Products, but in varying proportions in different Food-stuffs.— Natural products such as the cereals and leguminous grains, animal foods, oils and fats, starches and sugars,

and vegetables and fruits contain in varying proportions the nutritive principles required. Stated generally, animal products supply proteids and fats, but no carbohydrates, except in the case of milk, which contains sugar. Leguminous grains or pulses, such as peas, lentils, and beans, are as rich in nitrogenous substances as meat and fish, and are also rich in carbohydrates and fats. The cereal food grains, such as wheat, barley, rye and oats, while containing a moderate amount of nitrogenous material, viz., about 12 per cent., contain large percentages of non-nitrogenous substances. Among the cereal grains rice is particularly poor in nitrogenous material, while oats and maize are the richest in fatty matters. Starches, sugars, and animal and vegetable fats and oils contain carbohydrates in large quantities, but no proteids. Vegetables and fruits contain acids and salts of special value to the human economy. Vegetable products are rich in potassium-salts, while animal foods are poor in them. It may be said that in European food meat supplies the proteids; bread, potatoes, &c., the starch; and butter the fat; while in tropical food the proteids are supplied mostly by fish, peas, beans, and other pulses; the starch by millet, cereals, manioc, yams, &c.; and the fat by vegetable-oils such as ground nut, &c.

The cereals include the large group of minor cereals or "millets." The most important of which are "great millet" or joar (*Sorghum vulgare*); spiked or bulrush millet, lájra (*Pennisetum typhoideum*); ragi (*Elusine coracana*); Italian millet (*Setaria italica*); and chena (*Panicum miliaceum*). The *S. vulgare* is inferior only to the best wheat for bread-making.

The pulses most commonly grown in India are:—

(1) *Cajanus indicus*, pigeon pea, *dal* or arahar.

(2) *Cicer arietinum*, chicken pea, gram, chhola or chena.

(3) *Dolichos biflorus*, the horse gram, kwithi kalai or kulthi.

(4) *Pisum arvense*, field pea, desi matar.

(5) *P. Sativum,* European and American pea, bilate matar.

(6) *Dolichos lablab vulgare,* Indian bean, Shim, popat.

(7) *Glycine soja,* the soy bean, Bhat or Gari-Kaldi.

(8) *Lathyrus sativus,* Kheshari, twi or tewra.

(9) *Lens esculenta,* the lentil, musuri.

(10) *Phaseolus aconitifolius,* moth, mothi or bhringi.

The composition and the relative value of the different food-stuffs have been worked out by many observers, among whom may be mentioned Playfair, Church, Moleschott, Parkes, Du Chaumont, Pavy, Mayer, Joule, Atwater, Voit, Rubner and Koenig. The animal foods used in the Tropics are fully represented by beef, mutton, fowl, fish, turtle, milk, cheese, butter and eggs. Their composition being as follows :—

ANIMAL FOODS.

	Proteids	Fats	Carbo-hydrates	Salts	Water
Beef (average meat) ...	20·96	5·41	—	1·14	72·03
Mutton (average)	17·11	5·77	—	1·33	75·99
Fowl (lean)...	19·72	1·42	—	1·37	76·22
Fish (cod)	16·23	0·33	—	1·36	72·35
Turtle (green), edible parts	18·5	0·5	—	1·2	79·8
Milk (cow)	4·20	3·70	4·50	0·7	86·0
,, (goat)	4·20	4·70	4·60	0·7	86·0
Cheese, Dutch (average) ...	28·21	27·83	2·50	4·86	36·60
Gruyère	29·49	29·75	1·46	4·92	34·38
Eggs	12·55	12·11	0·53	1·12	73·47
Butter (fresh)	2·00	85·00	—	1·00	12·95

The oily foods are of animal and vegetable origin. Of the first kind, the most commonly used are : butter, ghee, which is melted butter, the oil from the liver of many fish, and the fat of beef and mutton ; of the second kind there are the vegetable-oils expressed from various seeds, and which are used either for cooking purposes or in place of butter. Such are the oils from the mustard-seed, the ground- or pea-nut (*Arachis hypogea*) ; coco-nut, soy bean, til (*Sesamum indicum*) ; Juvia nut (*Bartholletia excelsa*) ; from the Dika butter, kernel of the stone of the

8

Dika fruit (*Irvingia barteri*); shea butter (*Butyrospermum parkii*); and kokam butter or mangosteen oil (*Geacina indica*). The oil or butter contains about 82 per cent. of oil or fat; ghee, if pure, 100 per cent.; the seeds from which the oils are expressed contain different percentages of oil, varying from 18·9 in the soy bean and 56 in the Juvia nut, to 73 in the kernel of the Dika. All oils expressed cold are purer than those expressed by any heating process.

Vegetable foods are represented by cereals, pulses, tubers, herbaceous vegetables and fruits. The following percentages of cereals and pulses are taken from Church's "Food Grains of India." (See p. 115.)

Of roots and tubers the chief are the sweet potato (*Ipomœa batatus*), yam (*Dencorea*), taro (*Colocaria esculenta*) and the cassava or manioc. There are two kinds of cassava plant, the sweet (*Manihot aipi*) and the bitter (*Manihot utilisimo*). The latter contains in its milky juice a certain amount of prussic acid which is washed away in preparing from it tapioca and cassava meal.

There is in the roots less than 1 per cent. of proteids and of fat and the value of them as foods is in the potash-salts and the amount of starch which they contain, the latter constitutent varying from 15 to nearly 30 per cent.; tapioca contains about 86 per cent. of starch. All the tubers contain a large percentage of water.

There is an abundance of vegetables and fruits of different kinds in the Tropics. Thus the egg-plant or brinjal, Indian-spinach, sag, papaya, banana, sugar-cane, mango, mangosteen, lichee, pine-apple, durian, jack-fruit, melon, custard-apple, tamarind and lime are the most common. The vegetables are valuable for the mineral-salts they contain, largely in the form of potash, and the fruits for the amount of sugar and vegetable acids, such as malic, tartaric, citric, &c. Bananas, grapes, dates, figs and raisins contain high percentages of sugar and free acids.

There is much variation in the relative proportions

CEREALS.

Grain, husked	Proteids	Fats or oil	Other non-nitrogenous material	Salts	Water	Fibre
Koda millet (*Paspalum scrobiculatum*)	7	2·1	77·2	1·3	11·7	0·7
Chena or Indian millet (*Panicum miliacum*)	12·6	3·6	69·4	1·4	12·0	1·0
Sanwa millet (*Panicum frumentaceum*)	8·4	3·0	72·5	1·9	12·0	2·2
Italian millet (*Setaria italica*) ...	10·8	2·9	73·4	1·2	10·2	1·5
Bulrush millet (*Pennisetum typhoideum*)	10·4	3·3	71·5	2·0	11·3	1·5
Job's tears (*Coia lachryma*) ...	18·7	5·2	58·3	2·1	13·2	1·5
Maize (*Zea mäys*)	9·5	3·6	70·7	1·7	12·5	2·0
Rice (*Oryza sativa*)	7·3	·6	78·3	·6	12·8	·4
Sugar cane (*Saccharum officinarum*)	·1	...	24·0 (sugar)	1·6	74·0	...
Great millet (*Sorghum vulgare*)	9·3	2·0	72·3	1·7	12·5	2·2
Oats (*Avena sativa*)	10·1	2·3	56·0	2·3	12·7	16·6
Ragi (*Eleusine coracana*) ...	7·3	1·5	73·2	2·3	13·2	2·5
Wheat (*Triticum vulgare*) ...	13·5	1·2	68·4	1·7	12·5	2·7
Barley (*Hordeum vulgare*) ...	11·5	1·3	70·0	2·1	12·5	2·6
Buckwheat and its allies:—						
Buckwheat (*Flagopyrum esculentum*)	15·2	3·4	63·6	2·1	13·4	2·3
Common amaranth (*Amarantus paniculatus*)	13·7	6·0	58·4	5·2	11·9	4·8

PULSES OR LEGUMINOUS SEEDS.

Guar-bean (*Cyamopis psoraliodes*)	29·8	1·4	46·2	3·1	11·8	7·7
Ground- or Pea-nut (*Arachis hypogea*)	24·5	50·0	11·7	1·8	7·5	4·5
Chick-pea (*Cicer arietinum*) ...	21·7	4·2	59·0	2·6	11·3	1·0
Vetchling (*Lathyrus sativus*) ...	31·9	·9	53·9	3·2	10·1	
Pea (*Pisum sativum*)	28·2	1·5	55·0	2·5	11·8	1·0
Lentil (*Lens esculenta*)	25·1	1·3	58·4	2·2	11·8	1·2
Soy bean (*Glycine soja*)... ...	35·3	18·9	26·0	4·6	11·0	4·2
Haricot-bean (*Phaseolus vulgaris*)	23·0	2·3	52·3	2·9	14·0	5·5
Mung-bean (Black gram and green gram) (*Phaseolus mungo*)	22·2	2·7	54·1	4·4	10·8	5·8
Moth-bean (*Phaseolus aconitifolius*)	23·8	·6	56·6	3·6	11·2	4·2
Catiang-bean (*Vigna catiang*) ...	24·1	1·3	56·8	3·5	12·5	1·8
Lablab-bean (*Dolichos lablab*) ...	24·4	1·5	57·8	3·0	12·1	1·2
Horse-gram (*Dolichos biflorus*)...	22·5	1·9	56·0	3·2	11·0	5·4
Pigeon-pea (Red gram) (*Cajanus indicus*)	17·1	2·6	55·7	3·8	13·3	7·5
Inga-bean (*Pithecolobium dulce*)	17·6	17·1	41·4	2·6	13·5	7·8

of the constitutents, for instance 100 parts of meat contain 12 per cent. of carbon and 3 per cent. of nitrogen, bread 37 per cent. of carbon and 1 per cent. nitrogen, beans 42 per cent. of carbon and 4·5 per cent. nitrogen, lentils 43 per cent. of carbon and 3·87 per cent. nitrogen, and oil 98 per cent. of carbon and only traces of nitrogen.

These variations, together with the fact that carbohydrates and fats cannot take the place of proteids and that the physiological needs of the body require a ratio of one part of nitrogen to about 15 or 16 parts of carbon, necessitate a mixture of food-stuffs to obtain the requisite proportions. A mixed diet in this sense may be obtained either from an admixture of animal and vegetable food-stuffs or from food-stuffs derived from the vegetable kingdom alone, but not from ordinary vegetables.

Rice, ragi, millets, maize and other cereals form as a rule the staple foods in the Tropics. They contain too small proportions of proteid and oil to be sufficient by themselves and accordingly their deficiencies are made up by an admixture with a small quantity of the leguminous grains. These, the pulses or grams and beans are particularly rich in nitrogenous, starchy and phosphorated principles. They contain at least 20 per cent. of proteids. The soy bean or oily pea of China and Japan has 35 per cent. while its percentages of oil (18·9) and mineral-salts (4·6) are also exceptionally large. The ground-nut is particularly remarkable for its high percentage of oil which reaches 56 per cent. Care, however, has to be taken in supplementing the deficiencies of the cereals by legumes, not to add too large quantities of these rich foods. From to 2 to 4 ozs. are generally sufficient and the amount should never exceed 7 ozs.

The Heat Value of the different Nutritive Principles.—The potential energy of food-stuffs or their fuel value is usually stated in large calories, or in England in foot-tons. A small calorie or heat-unit is the amount of heat required to raise 1 gram of water 1° C. and a large calorie

is the amount of heat required to raise 1 kilogram or 1 litre of water 1° C. The large calorie is therefore equal to 1,000 heat-units or small calories, and when converted into mechanical force will raise 425 kilograms through 1 metre. In England the heat-unit is the amount of heat required to raise 1 lb. of water 1° F. or 772 lbs. a foot high. One large calorie or 425 kilogram metres is equal to 3,060 foot-pounds or that number of pounds raised through 1 foot, which when divided by 2,240 to reduce foot-pounds to foot-tons equals 1·32 foot-tons. With one large calorie or 425 kilogram metres being equal to 1·32 foot-tons, 1,000 kilogram metres would be equal to 3·1 foot-tons.

Outside the body the fuel value of proteid is placed at 5·7 large calories, but as has been stated this is not all available for the nutrition of the body for the whole is not assimilated, and even of that portion which is assimilated, all is not available, for certain incompletely oxidised nitrogenous products are excreted as urea from the body. Rubner after careful investigation sets down the available fuel value of each of the food constituents as follows :—

	Large calories
1 gram of proteid	4·1
1 ,, fat	9·3
1 ,, carbohydrate	4·1

From the above data the calorific value of any diet can be readily calculated.

Thus if Voit's standard diet be taken which consists of 105 grams of available proteid, 56 grams of fat, and 500 grams of carbohydrate, the fuel value is 3,000 large calories. Thus :—

			Large calories
105 grams of	proteid	× 4·1 =	430
56 ,,	fat	× 9·3 =	520
500 ,,	carbohydrates	× 4·1 =	2,050
			3,000

By multiplying the 3,000 by 425, the number of kilogram metres of force which each large calorie represents, the amount of available mechanical energy in the

diet is given in kilogram-metres and by the data already mentioned can be converted into foot-tons.

The ascertained Nutritive Value of Actual Diets.—The definite information obtained relating to proteids, carbohydrates and fats and the respective rôles they play as tissue-formers and energy-producers has been supplemented by investigations of a physiological and chemical nature into the nutritive value of actual diets in use among persons engaged in various pursuits. The facts so obtained have in their turn served as a guide for the construction of ideal standard diets, not in regard to the actual kind of foods to be used but with reference to the amounts of proteid, carbohydrate and fat requisite for the maintenance of health. From these observations it has been found that the daily waste of a man of 70 kilograms or 11 stones doing ordinary work on an ordinary diet actually amounts to about 20 grams of nitrogen and 320 grams of carbon, which is in the proportion of 1 of nitrogen to 16 of carbon; that the food supplied must contain a sufficiency of nitrogen to make up the waste and also to provide by its carbon elements at least 3,000 large calories, and that the ratios between the constituents of the food shall be in definite proportions.

Authority	Proteid. Grams	Fat. Grams	Carbo-hydrates. Grams	Total amount of food-stuffs	Calories	Nutrient ratio
Hutchison ...	125	50	500	676	3,027	1 : 5
Schmidt	105	63	541	709	3,235	1 : 6
Munk	105	56	500	661	3,022	1 : 6
Wolff	125	35	540	700	3,030	1 : 5
Voit	118	56	500	674	3,055	1 : 5
Rubner	127	52	509	688	3,092	1 : 5
Playfair	119	51	531	701	3,140	1 : 5
Moleschott ...	130	40	550	720	3,160	1 : 5
Atwater	125	125	450	700	3,520	1 : 6
Studemund ...	114	54	561	729	3,229	1 : 6
Forster	134	79	523	736	3,430	1 : 5

The above table gives the constituent amounts of some of these standard diets. In studying them it has

always to be remembered that proteids contain but 16 per cent. of nitrogen. So that if 16 grams of nitrogen have to be supplied, 100 grams of proteid have to be provided, and if 20 grams of nitrogen are necessary, then 125 grams of proteid must be given. The diets are for an adult man weighing 70 kilograms or 11 stones, and doing ordinary work.

The daily amount of food-stuff in these diets ranges from 661 to 736 grams, or from 9·4 to 10·5 grams per kilogram of body-weight. In English terms these figures represent 21·2 ounces, and 23·6 ounces or ·137 ounces and ·146 ounce per pound of body-weight. As the total daily amount necessarily varies according to individual weight, it is best for purposes of calculation to state the quantities of the food constituents in either grams per kilogram of body-weight, or in ounces per pound of body-weight. Thus, taking Voit's standard diet for ordinary work, the several quantities may be stated as follows :—

	Grams in 24 hours	Grams per kilo of body-weight	Ozs.	Ozs. per lb. body-weight
Proteid	118	1·7	3·8	·025
Fat	56	·8	1·8	·012
Carbohydrates ...	500	7·1	16·0	·110
	674	9·6	21·6	·147

With harder work extra amounts of carbohydrates and fats, which are energy producing constituents, are added, and a slightly increased amount of proteid is added to make up for any extra wear and tear.

Dealing for the present with ordinary work it is important to call attention to the fact that recent experiments made by Chittenden on soldiers, professional men, and athletes, tend to show that these European standard diets, which have held their place without question for many years, err on the side of containing too much proteid, and that at most half the amount of

proteid recommended in the majority of these standards is sufficient to meet the ordinary physiological needs of the body; and further, that greater efficiency in working power, and a better feeling of well-being and health is attained by a smaller amount of proteid than with the excessive amounts taken in ordinary diets, which, as a rule, contain even more than there is in the standard diets. The evidence put forward in favour of these views is strong, and is supported by the fact that nations such as the Japanese or Indians, living a simpler life, and more given to vegetarianism than the European or American, are maintained in health on a much smaller amount of proteid than these standards indicate as necessary.

Chittenden concludes from his experiments that the average need for proteid food is met by a daily metabolism equal to an exchange of 0·12 gram of nitrogen per kilogram of body-weight, which would be supplied by ·75 gram of proteid matter daily per kilogram. As, however, the intake of proteid matter must be in excess of the actual proteid needs, owing to the fact that not all of the proteid is available, and the further fact that there is a difference in the digestibility and the degree of assimilation of animal and vegetable foods, the required daily intake of proteid for safety's sake is placed at 0·85 gram per kilogram body-weight. Thus, for a man weighing 70 kilograms or 154 lbs., there would be required 0·85 gram per kilogram, *i.e.*, 59·5 or 60 grams daily of proteid to meet the daily needs of the body. This is very different from the 1·7 gram per kilogram of body-weight, or 118 grams of Voit, or the 1·9 gram per kilogram, or 134 grams of Forster. It at least shows that the large amounts of proteid which were considered indispensable are by no means necessary, and that diets containing a much more moderate quantity, ranging from one-half to three-quarters of the recognised amount per kilogram of body-weight can be used not only without injury but with actual benefit.

Chittenden gives the following table containing some of the results collated by Kintaro Oshima from dietary studies on various classes of Japanese whose food was mainly vegetable, but generally with some admixture of fish or meat :—

Subjects	Body-weight. Kilos.	Digestible Nutrients and Energy per Man per Day			
		Proteid. Grams	Fat. Grams	Carbo-hydrate. Grams	Fuel values. Calories
School business agent ...	57·5	65·3	11·3	493·8	2,467
Physician	...	61·9	8·0	468·5	2,317
Merchant	47·6	81·5	19·6	366·2	2,082
Medical student	49·0	74·8	11·2	326·9	1,811
,, ,, ...	48·5	64·7	5·1	469·6	2,305
Military cadets	...	72·3	11·7	618·1	3,021
Prisoners without work ...	47·6*	36·3	5·6	360·4	1,726
,, at light work ...	48·0*	43·1	6·2	448·9	2,112
,, at hard work ...	...	56·7	7·5	610·8	2,884
Physician	40·2	48·3	15·5	438·2	2,201
Hygienic assistant	40·5	46·5	19·5	485·3	2,430
Medical student	51·0	42·8	14·0	488·2	2,160
Police prisoners	...	42·7	8·7	387·3	1,896
Army surgeon	54·0	79·3	11·7	502·0	2,567
Soldier	66·7	75·8	13·5	563·8	2,828
,, ...	61·0	58·8	11·3	467·8	2,330
,, ...	56·7	55·2	10·9	459·6	2,276

* Average weight of twenty subjects.

The figures show a much smaller intake of proteid than is generally the case with Europeans and Americans.

The Nutrient Ratio or the Ratio of Nitrogenous to Non-Nitrogenous Principles.—According to the hitherto accepted standards, the nutrient ratio or the ratio of nitrogenous food-stuffs to non-nitrogenous does not vary much. Setting aside for the moment the conclusions of Chittenden, which favour a nutrient ratio of 1 in 9 or even 1 in 10, practical experience which has hitherto been the guide, has fixed the ratio of nitrogenous food-stuffs to non-nitrogenous in a good diet to be not less than 1 in 6, and the ratio of oils or fats to the total non-nitrogenous constituents, both reckoned as starch, to be at least 1 in 6. Further, the ratio of oils or fats to pro-

teids is generally not less than 1 in 2, and should not be less than 1 in 3.

The ratio thus stated would be represented as

Proteids	Carbohydrates	Oil
3	15	1

but in most diets the relative quantities of proteid to carbohydrates and to oil are much greater, as is to be seen in the standard diets already given.

In reckoning fat as taking the place of starch, the weight of oil or fat should be multipled by 2·4, and added to the weight of the starchy constituent.

The rarity of finding these ratios in any single natural food-stuff may be exemplified by the fact that Church[1] states that out of the food grains of India only 4 or 5 approach the nutrient ratio of 1 in 5. These are—buckwheat, husked (1 in 4·7); wheat (1 in 5·2); peanuts, whole seeds (1 in 5·2), and amaranth, whole seeds (1 in 5·2).

Other food grains show a very marked divergence from the standard nutrient ratio, thus:—

	Nutrient ratio
Ragi (*Eleusine coracana*)	1 : 13·0
Rice (cleaned)	1 : 10·8
Maize (whole)	1 : 8·3
Chick-peas	1 : 3·3
Pigeon-peas	1 : 3·0
Soy beans	1 : 2·0

It is clear that to obtain for the daily diet the required amount of proteids in cereals such as ragi, rice, or maize, an excessive quantity of starch would have to be consumed, while in the case of pulses, like chick-peas, pigeon-peas, and soy beans, which contain a large amount of proteids, the starch would be deficient. It needs a proper admixture of pulse and cereal to correct the deficiencies and excesses of each, and bring the diet near the standard ratio. A mixed diet, moreover, has been found to favour absorption.

A higher proportion of nitrogenous to non-nitrogenous material than 1 in 6 is necessary for infants, children,

[1] "Food Grains of India." By A. H. Church, 1886.

and youths, for the purposes of growth; to them more nitrogenous food-stuffs is given than to fully-matured adults. Milk, the diet of infants, contains these nutrient principles in the proportion of 1 to 3, and in the diet of a child they should be about 1 in 4. More nitrogenous material is also needed during extra hard work. In the case of adults, should Chittenden's teachings be followed, the nutrient ratio will be very much altered, and it will be nearer 1 in 9 or 1 in 10 than 1 in 5 or 1 in 6. In this respect, the ratio would approximate to that in the diet of the peasants in Japan, where it varies from 1 in 8 to 1 in 10, and to the Sepoy in Madras, where the ratio was found by McNally to be 1 in 9. The lowest diet of the Madras famine code, with rice as the staple, was 1 : 9·5.

There can be little doubt that the customs and habits of Europeans, especially in towns, tend generally toward a high nutrient ratio, and those of Asiatics incline to a low one. Probably the mean is nearer the requirements of health.

In the construction of European standard diets, the basis has generally been persons weighing 70 kilograms or 154 lbs., and doing a work of 300 foot-tons per day, or about 2 foot-tons per 1 lb. of body-weight. In Indian and Japanese dietary tables the lesser body-weight of 105 lbs. has usually formed the basis, the 2 foot-tons per 1 lb. of body-weight being retained.

Church gives the following standard diets for Indians weighing 105 lbs. expressed in avoirdupois ounces and decimals of an ounce:—

Church's Standard Diet for Indians.

Ration	Albuminoid or proteid	Oil	Starch	Starch equivalent	Nutrient ratio
Bare sustenance	2·1	0·752	7·520	9·250	1 : 4·34
Moderate work	2·954	1·412	12·531	15·779	1 : 5·34
Hard work	3·635	2·506	11·190	16·954	1 : 4·66

To obtain these the total weight of pulse and cereal and added oil will vary according to the natures of the pulse and cereal employed, so that in the ration for bare sustenance 12 to 14 ozs. of food-stuffs are needed ; for moderate work, 20 to 23 ozs. ; and for hard work, 21 to 25 ozs.

There are many combinations of food materials that can be made to approach these figures closely. Exactness is, of course, not practicable, and approximations only can be obtained. Church lays down two guiding principles. One is to keep down the pulse constituent to an amount not exceeding 7 ozs. per diem, and, if possible, not more than 5 ozs., and the other is, to ensure the presence of a sufficiency of proteids or albuminoids, as he calls them, by increasing the cereal constituents of the ration, even if in so doing the quantity of starch required be thereby raised above the necessary amount. The addition of 4 or 5 ozs. of fresh vegetables, such as onions, potatoes, and melons, are extremely useful in supplying some of the constituents in which a rice or millet or pulse diet is deficient, and in adding variety both of flavour and of texture or consistence to food which otherwise might be monotonous or unpalatable. Allowance must always be made for waste in the preparation of food-stuffs, and for portions that are undigested, 5 per cent. excess is generally allowed on this account. In the case of inferior samples of food-stuffs, 5 per cent. is usually added to the stated amounts. McNally, in a useful table, gives the amount of each constituent in an ounce of some of the principal food constituents which is here reproduced to facilitate the construction of dietaries (p. 125.) Church gives two other tables which are also useful (pp. 126, 127).

Construction of Dietaries.—From these tables it will be easy to ascertain whether a certain dietary in use is up to the standard in every respect, or in the event of having to construct a diet, it will be possible to do so by a reference to the tables, bearing in mind the standard

to be attained. Thus, for bare sustenance, 12 to 14 ozs. of food-stuff are needed, for moderate work 20 to 23 ozs., and for hard work 21 to 25 ozs. Church's tables only show the proteids and starch, and accordingly there would have to be added a certain quantity of vegetable-oil, except in the case of soy beans and other legumes that happen to be rich in oil.

TABLE SHOWING THE AMOUNT OF CONSTITUENTS IN EACH OUNCE OF FOOD-STUFF. McNALLY.

Food-stuffs	Albumenoid or proteids	Starch or sugar	Oil	Minerals	Fibre	Water
Cereal Grains—						
Rice	0·073	0·791	0·006	0·006	0·014	0·128
Koda	0·070	0·712	0·021	0·013	0·007	0·117
Ragi	0·073	0·732	0·015	0·023	0·025	0·132
Gundli	0·091	0·690	0·036	0·035	0·046	0·102
Maize	0·095	0·707	0·036	0·017	0·020	0·125
Joar	0·093	0·723	0·020	0·017	0·022	0·125
Bajra	0·104	0·715	0·033	0·020	0·015	0·113
Kagni...	0·108	0·734	0·029	0·012	0·015	0·102
Chena	0·126	0·694	0·036	0·014	0·010	0·120
Wheat	0·135	0·684	0·012	0·017	0·027	0·125
Amaranth... ...	0·137	0·584	0·060	0·052	0·048	0·119
Leguminous Grains—						
Chick-pea	0·217	0·590	0·042	0·026	0·016	0·115
Mung gram	0·227	0·558	0·022	0·044	0·048	0·101
Pea	0·236	0·575	0·015	0·025	0·010	0·118
Lentil	0·249	0·595	0·013	0·022	0·012	0·118
Ground-nut	0·245	0·117	0·500	0·018	0·045	0·075
Soy bean	0·353	0·694	0·189	0·046	0·042	0·110
Animal Foods—						
Lean meat	0·183	...	0·049	0·048	...	0·720
Fish	0·160	...	0·050	0·010	...	0·780
Eggs	0·140	...	0·105	0·015	...	0·740
Milk	0·048	0·042	0·033	0·008	...	0·870
Starches and Sugars—						
Arrow-root	...	0·83	...	...	...	0·17
Sugar	...	0·945	...	0·005	...	0·050
Oils and Fats—						
Butter	0·040	...	0·810	0·025	...	0·125
Ghi and oil	...	...	1·000	...	...	...
Vegetables and Fruits—						
Starchy and saccharine (potato or plantain)	0·025	0·211	0·001	0·013	0·010	0·740
Green and watery (cabbage)	0·002	0·058	0·005	0·007	0·018	0·910

TABLE I.—ALBUMINOIDS AND STARCH EQUIVALENTS IN CEREALS AND BUCKWHEATS. CHURCH.

(The figures represent ounces and decimals of an ounce.)

	1 oz.	2 oz.	3 oz.	4 oz.	5 oz.	6 oz.	7 oz.	8 oz.	9 oz.
Ragi									
Albuminoids ...	·059	·118	·177	·236	·295	·354	·413	·472	·531
Starch	·764	1·528	2·292	3·056	3·820	4·584	5·348	6·112	6·876
Koda									
Albuminoids ...	·07	·14	·21	·28	·35	·42	·49	·56	·63
Starch	·82	1·64	2·46	3·28	4·10	4·92	5·74	6·56	7·38
Rice									
Albuminoids ...	·073	·146	·219	·292	·365	·438	·511	·584	·657
Starch	·797	1·594	2·391	3·188	3·985	4·782	5·579	6·376	7·173
Sánwa									
Albuminoids ...	·084	·168	·252	·336	·420	·504	·588	·672	·756
Starch	·794	1·588	2.382	3·176	3·970	4·764	5·558	6·352	7·146
Gundli									
Albuminoids ...	·091	·182	·273	·364	·455	·546	·637	·728	·819
Starch	·773	1·546	2·319	3·092	3·865	4·638	5·411	6·184	6·957
Maize									
Albuminoids ...	·095	·190	·285	·380	·475	·570	·665	·760	·885
Starch	·790	1·580	2·370	3·160	3·950	4·740	5·430	6·320	7·110
Joár									
Albuminoids ...	·093	·186	·279	·372	·465	·558	·651	·744	·837
Starch	·769	1·538	2·307	3·076	3·845	4·614	5·383	6·152	6·921
Shama									
Albuminoids ...	·096	·192	·288	·384	·480	·576	·672	·768	·864
Starch	·757	1·514	2·271	3·028	3·785	4·542	5·299	6·056	6·813
Bájra									
Albuminoids ...	·104	·208	·312	·416	·520	·624	·728	·832	·936
Starch	·791	1·582	2·373	3·164	3·955	4·746	5·537	6·328	7·119
Kángni									
Albuminoids ...	·108	·216	·324	·432	·540	·648	·756	·864	·972
Starch	·801	1·602	2·403	3·204	4·005	4·806	5·607	6·408	7·209
Barley									
Albuminoids ...	·115	·230	·345	·460	·575	·690	·805	·920	1·035
Starch	·730	1·460	2·190	2·920	3·650	4·380	5·110	5·840	6·570
Chena									
Albuminoids ...	·126	·252	·378	·504	·630	·756	·882	1·008	1·134
Starch	·777	1·554	2·221	3·108	3·885	4·662	5·439	6·216	6·993
Amaranth									
Albuminoids ...	·143	·286	·429	·572	·715	·858	1·001	1·144	1·287
Starch	·760	1·520	2·280	3·040	3·800	4·560	5·320	6·080	6·840
Wheat									
Albuminoids ...	·135	·270	·405	·540	·675	·810	·945	1·080	1·215
Starch	·712	1·424	2·136	2·848	3·560	4·272	4·984	5·696	6·408
Buckwheat									
Albuminoids ...	·152	·304	·456	·608	·760	·912	1·064	1·216	1·368
Starch	·714	1·428	2·142	2·856	3·570	4·284	4·998	5·712	6·426
Quinoa									
Albuminoids ...	·192	·384	·576	·768	·960	1·152	1·344	1·536	1·728
Starch	·578	1·156	1·734	2·312	2·890	3·468	4·046	4·624	5·202

TABLE II.—ALBUMINOIDS AND STARCH EQUIVALENTS IN PULSE. CHURCH.
(The figures represent ounces and decimals of an ounce.)

	1 oz.	2 oz.	3 oz.	4 oz.	5 oz.	6 oz.	7 oz.
Soy Beans							
Albuminoid ...	·353	·706	1·059	1·412	1·765	2·118	2·471
Starch	·694	1·388	2·082	2·776	3·470	4·164	4·858
Vetchlings							
Albuminoid ...	·319	·638	·957	1·276	1·595	1·914	2·233
Starch	·521	1·042	1·563	2·084	2·605	3·126	3·647
Lupines							
Albuminoid ...	·317	·634	·951	1·268	1·585	1·902	2·219
Starch	·452	·904	1·356	1·808	2·260	2·712	3·164
Vetches							
Albuminoid ...	·315	·630	·945	1·260	1·575	1·890	2·205
Starch	·497	·994	1·491	1·988	2·485	2·982	3·479
Guar							
Albuminoid ...	·298	·596	·894	1·192	1·490	1·788	2·086
Starch	·494	·988	1·482	1·976	2·470	2·964	3·458
Lentils							
Albuminoid ...	·249	·498	·747	·996	1·245	1·494	1·743
Starch	·595	1·190	1·785	2·380	2·975	3·570	4·165
Pea-nuts							
Albuminoid ...	·245	·490	·735	·980	1·225	1·470	1·715
Starch	1·267	2·534	3·801	5·068	6·335	7·602	8·869
Moth							
Albuminoid ...	·238	·476	·714	·952	1·190	1·428	1·666
Starch	·580	1·160	1·740	2·320	2·900	3·480	4·060
Peas							
Albuminoid ...	·236	·472	·708	·944	1·180	1·416	1·652
Starch	·575	1·150	1·725	2·300	2·875	3·450	4·025
Catiang-beans							
Albuminoid ...	·231	·462	·693	·924	1·155	1·386	1·617
Starch	·578	1·156	1·734	2·312	2·890	3·468	4·046
Haricots							
Albuminoid ...	·230	·460	·690	·920	1·150	1·380	1·610
Starch	·576	1·152	1·728	2·304	2·880	3·456	4·032
Mung-beans							
Albuminoid ...	·227	·454	·681	·908	1·135	1·362	1·587
Starch	·608	1·216	1·824	2·432	3·040	3·648	4·276
Horsegram							
Albuminoid ...	·225	·450	·675	·900	1·125	1·350	1·575
Starch	·603	1·206	1·809	2·412	3·015	3·618	4·221
Lablab-beans							
Albuminoid ...	·224	·448	·672	·896	1·120	1·344	1·568
Starch	·574	1·148	1·722	2·296	2·870	3·444	4·018
Pigeon-peas							
Albuminoid ...	·203	·406	·609	·812	1·015	1·218	1·421
Starch	·596	1·192	1·788	2·384	2·980	3·376	4·172
Chick-peas							
Albuminoid ...	·195	·390	·585	·780	·975	1·170	1·365
Starch	·643	1·286	1·929	2·572	3·215	3·858	4·501
Inga-beans							
Albuminoid ...	·176	·352	·528	·704	·880	1·056	1·232
Starch	·807	1·614	2·421	3·228	4·035	4·842	5·649

To ascertain by McNally's table, whether a diet is sufficient, the quantity in ounces of each food-stuff contained in the ration should be multiplied by the numbers opposite it in the table, and it can be seen whether the result approximates to what is necessary in a diet, according to the circumstances of age, body-weight and work.

Several examples of rations may be here given taken from Church, and with his explanations. The first is the construction of a diet containing soy beans (*Dolichos soja*) and rice as the substantive constituents. It has already been said that a dietary for moderate work demands 2·954 proteid, 1·412 oil, and 12·531 starch, the starch equivalent of which is 15·779. Referring to the tables it is found that :—

	Proteid	Starch
Soy beans, 5 oz. furnish	1·765	3·470
Rice, 16 ozs. ,, ...	1·163	12·752
	2·928	16·222

As the oil, however, in this ration is but 1 oz., and should be 1·4 ozs., it will be necessary to add the lacking four-tenths. To do this without disturbing the ration $1\frac{1}{2}$ ozs. of rice ought to be withdrawn, and $\frac{1}{2}$ oz. of soy beans added. Then the amounts will be :—

	Proteid	Starch
Soy beans, $5\frac{1}{2}$ oz. furnish	1·942	3·817
Rice, $14\frac{1}{2}$ oz. ,, ...	·954	11·552
Oil, $\frac{4}{10}$ oz., equal to	*Nil*	·920
	2·896	16·289

A second example may be given in which a ration is used containing rice and a kind of pulse in which there is little more than a trace of oil, and where the albuminoids are present in no more than the ordinary proportions. Such a pulse is the lablab-bean (*Dolichos lablab*, Linn.). The following amounts will be necessary :—

	Proteid	Starch
Lablab-beans, 8 ozs. furnish ...	1·792	4·592
Rice 16 ozs. ,, ...	1·168	12·752
	2·960	17·344

The dietary requires, however, to include 1·41 ozs. of oil. It is therefore necessary to supplement the deficiency in this constituent by adding at least 1 oz., and the ratio is made up by withdrawing 4 ozs. of rice and adding 1 oz. of lablab-beans. Thus :—

			Proteids	Starch
Lablab-beans,	9 ozs. furnish	...	2·016	5·166
Rice	12 ozs. ,,	...	·876	9·664
Oil	1 oz. equal to	...	*nil*	2·300
			2·892	17·130

A still larger proportion of lablab would be needed to realise the proper ratio between the constituents of this dietary; but 9 ozs. of pulse is already too large a quantity to be consumed daily, and accordingly there ought to be associated with it a third aliment; wheat or one of the millets might advantageously replace a part of the rice.

A third example may be given of millets and pulse being used together and without rice. The millets are comparatively rich in proteids, and this allows of the lowering of the amount of ordinary pulse employed with them. If mung-beans (*Phaseolu mungo*) and bajra (*Pennisetum typhoideum*) be taken, then the following amounts will be necessary :—

			Proteids	Starch
Mung-beans,	5½ ozs. furnish	...	1·249	3·344
Bajra	16 ozs. ,,	...	1·664	12·656
			2·913	16·000

These quantities of mung and bajra contain only ·65 oz. of oil. This leaves ·75 oz. to be supplied. If ¾ oz. be introduced, 3 ozs. of bajra must be withdrawn, and 1½ ozs. of mung added :—

			Proteids	Starch
Mung-beans,	6½ ozs. furnish	...	1·587	4·276
Bajra	13½ ozs. ,,	...	1·352	10·183
Oil	¾ oz. equal to	...	*nil*	1·725
			2·939	16·184

Moleschott's standard diet, which is a higher one than Church's, and which contains 130 grams of proteid and 550 of carbohydrate, is generally followed in Indian

Government institutions, proper reductions being made for less body-weight. Possibly owing to the exceptional and depressing conditions under which the inmates are situated in jails and asylums, a more generous diet is required, but it is doubtful whether, under ordinary circumstances, a diet so very rich in proteid is required, and whether a diet more in conformity with Chittenden's standard, and below that fixed by Church, is not more suitable, and more in accordance with the requirements of a high state of health.

In respect to jails, Captain W. M'Cay and Dr. Satis Chundra Banerjee, as a result of an examination of the food-stuffs used in the Bengal jails, come to the conclusion that rice enters too largely into the diet, and that although the amount of proteid is ample in the quantity of rice and dhal given, yet owing to it being presented in a form that is not easily assimilated there is much waste of proteid matter, amounting to 20 to 30 per cent. and they are disposed to think that this large nitrogenous residue is likely to set up intestinal catarrh, and predispose to dysentery. They also point out that the carbohydrate element, which amounts to about 700 grams, owing to the large amount of rice taken, is some 150 grams beyond even Moleschott's standard, and is far in excess of the bodily requirements, and that the salt given is about four or five times the amount required for the needs of the system.

It will be gathered from the foregoing that the diet could be improved by adding other food-stuffs containing more assimilable proteids than those of rice, reducing the quantity of rice, and lessening the amount of salt.

Monotony in diet must be avoided. Want of variety, even with the most nutritious of food-stuffs, will tend to pall the appetite and bring on disturbances of the alimentary canal.

In arranging diets for large numbers, there should be systematic classification. Children require more food

per unit of body-weight than adults, and a higher relative proportion of proteid, and a separate dietary should be arranged for them. Adults also vary much in weight, and in order that some should not be over-fed, and others under-fed, by a diet based on the average weight, the adults should be divided into classes according to weight, and the ration given to each class should meet the requirements of the heaviest in it. There is less risk in over-feeding than in under-feeding.

CHAPTER VII.

FOOD IN RELATION TO HEALTH AND DISEASE.

Man requires a mixed diet and, with some reservations relating to custom and climate, it is a matter of indifference whether the mixed diet is obtained wholly from vegetable products, or partly from animal and partly from vegetable products.—The proteids of meat are more easily assimilated than those of vegetable products and repair the tissues more rapidly.

Over 97 per cent. of the proteids from animal foods are absorbed when taken in ordinary quantities, 85 per cent. of the proteids from cereals and the whole of the sugar are assimilated, and only 80 per cent. of the proteids from vegetables and fruits.

But the more rapidly this assimilation goes on the more rapidly are toxic substances formed, as the by products of the breaking down and oxidation of proteids, and there is the chance of these being produced in excess.

The best combination of proteids seems to be a mixture of flesh, bread and vegetables, in which the proteids from animal foods do not exceed 50 per cent. Any percentage above this is too rich in animal food.

When the proteids are habitually taken in excess the toxins are apt to accumulate in the blood, and, besides exerting an injurious influence on muscle and nerve, place a strain on the functions of the liver and kidneys.

This is peculiarly apt to occur in warm climates, where, owing to the diminished work of the lungs, oxidation has already been interfered with and more work has been thrown on the liver and organs to get rid of waste pro-

ducts which are not always sufficiently elaborated, a condition of things that is aggravated frequently by an enforced sedentary life.

Whether grains or meat or fish shall enter most largely into the diet depends a great deal on climate; on the habits of the people, whether indolent or active, and on other circumstances.—In countries which are hot, in which animals are scarce or liable to parasitic disease, where oxen are valuable as beasts of burden, and where fruits and vegetables are abundant, the inhabitants as a rule live mainly on a vegetable diet.

In India, for example, the principal article of food in Bengal, Burmah, Madras, and Assam is rice; mixed with pulse, and a little ghee or melted butter, and a few vegetables and fruits, it suffices for the wants of the people. In Northern India, which is not a rice-growing country, the millets and pulses are eaten by the poor, while the richer classes are able to afford wheat and barley. Indian corn is eaten by all. There are Hindus who take no animal food beyond that of milk and ghee. There are others who take fish and eggs, and others who eat certain kinds of meat, abstaining, however, from beef and pork. The Sikhs and the Punjaubis are reputed to be the finest soldiers in India, with the exception, perhaps, of the Ghoorkhas, who are hill men. The Sikhs eat goat and mutton. The Punjaubi Hindus eat no meat, but the Punjaubi Mahomedans do. It should be noted that Northern India has a prolonged cold season. The meat, however, is taken neither so frequently nor in such quantities as is common among Europeans. With the Chinese and Japanese, fish with rice and sometimes a little pork and poultry form the basis of their diet.

The inhabitants of hot climates are generally content with milk products, pulses, fruits and sugars, but, though cereal grains as a rule form the chief foods of the inhabitants of hot countries, rice being the staple food wherever there is plenty of water and rain, still there are large populations even in hot climates whose food is of an animal

nature. Thus, the Arabs of East Africa, the Pampas Indians and the Abyssinians are often quoted as instances of consumers of large quantities of meat. They are all very active races.

Exceptions are useful for the purpose of showing that it is possible for man to adapt himself in any circumstances to any kind of food, so long as it contains nourishment, but it by no means follows that it is the most suitable.

In cold countries, where different conditions prevail, the inhabitants are chiefly meat-eaters, and the colder the climate the more oil is added to the food. The Esquimaux are an animal-feeding people, and eat large quantities of fat, which supplies fuel to keep up the temperature of the body under conditions of intense cold. Time crystallizes these customs into fixed habits, which cannot be readily changed without risk of injury to health. Meat-eaters are likely to suffer if they suddenly change into grain-eaters, and *vice-versâ*, grain-eaters suffer if they change to meat-eaters. The large quantities of starchy food which grain-eaters consume and experience no difficulty in digesting would be injurious to a meat-eater, while the less bulky but more nutritious food of the meat-eater would not satisfy the hunger of a grain-eater or fruitarian.

There is an absolute necessity of modifying the diet to suit it to the physiological requirements of varying climates. Disregard of this law has had many an illustration as its results. In the first Burmese war, for six and a half months the troops were fed on salt rations almost exclusively, and 48 per cent. of them perished within ten months, principally of scorbutic dysentery, while in the regiment of the Cameronians 700 out of 900 were invalided from the same cause in two months.

An excess of fresh meat also produces intestinal derangement. This was shown in the French campaign in Algeria, when the men ate excessively of captured mutton and rapidly succumbed to intestinal disease.

The same was noticed in the American Army during the Civil War. An epidemic of intestinal catarrh or dysentery invariably followed a raid in the enemy's country and the capture of quantities of live stock, which was given to the men in excessive amount. Something very similar to this occurred among some of the regiments in South Africa in the recent war. To excessive quantity, however, may also have been added a poisonous quality, from the animals having been overdriven.

The defect likely to be in the diet of a European in the Tropics is that it is too nitrogenous and fatty.—The European has been accustomed to animal food, which mainly consists of nitrogenous substances and fats, and there is a tendency to continue these in the same proportions as before.

When the Aryans first descended into the plains of India they were meat-eaters, but the experience of the centuries evidently taught them to be vegetarians, or to be very sparing in the amount of meat they ate, and at the same time to become total abstainers. This is an experience, the lessons of which Europeans who go to the Tropics are inclined to ignore. Accustomed to living well in their own country, in which large quantities of meat, fats and rich food, as well as wines and spirits, form an important part of their diet, they are tempted to continue, as closely as possible, a similar diet in the Tropics.

It has already been mentioned that in Europe the consumption of proteids in the form of meat tends to be excessive, and that the breaking down of proteids in the body gives rise to a residue of incombustible matter in the form of crystalline nitrogenous products consisting of urea and purin bodies, which circulating in the system in excess, are liable to exercise a deleterious influence on the system. Excess of proteids under ordinary circumstances puts a strain on the liver and kidneys. That strain is to be particularly avoided in

the Tropics where, by reason of climate, the functional activities of these organs have been increased. If too much meat is taken in the Tropics the liver and kidneys suffer ; fermentation, catarrh and dyspepsia affect the digestive tract, and there may be fever and a certain amount of full-bloodedness predisposing to sun-stroke.

Such unhealthy conditions should be rectified by a reduction in the amount of animal food and a more liberal allowance of vegetable food, which supplies the necessary constitutents in a less stimulating form more suited to a climate in which congestion of the abdominal viscera is especially apt to occur.

In the Tropics, where the temperature is nearly as high and sometimes higher than that of the body temperature, there is not the same necessity for fatty foods as in colder climates, and the substitution of fruits and farinaceous substances for oleaginous articles will not only be more grateful to the taste but will prevent intestinal disorders which, under the circumstances, are likely to be produced by a diet which is too fatty. It would be a mistake, however, to exclude meat altogether from the diet. Old records establish that high feeding and much drinking were considered to be necessary to counteract the debilitating effects of the climate. Heavy dinners begun at midday and continued well into the afternoon, were responsible for many duels, and that irascibility and jaundice which gave rise at one time to the popular notion that the latter were the characteristics which belonged to the Nabobs of India, who were fortunate enough to return to their native land.

Although there is still much illness due to unsuitable diet, yet the gross feeding and heavy beer drinking of former days have gone. The tendency is towards a much simpler fare, in which less meat is eaten, and less alcohol drunk. Rice, pulse, fruit, and vegetables enter, as a rule, largely into the *menu* at breakfast and tiffin. For dinner there is little difference between the *menu* in tropical climates and that in Europe. This is not a

vegetable diet, but it is one which contains a very much less quantity of concentrated proteids in the form of meat than that which entered into the meals of former days. It is also associated with the consumption, at luncheon and dinner, of very much less alcohol, whether in the form of beer, whisky and soda, or heavy wines. The substitution of the afternoon tea for the customary whisky and soda, or brandy and soda, also contributes in no small degree to a healthier condition.

The gradual tendency to adopt a more or less modified vegetarianism in comparison with the richer and more animal diets of olden days, in order to reach a proper diet conformable to racial customs, and yet adjusted to the conditions of climate, has, in the first instance, been due to the teaching of experience which has shown the ill-effects of a diet too rich in meats, and in the second instance to seeing large populations in the Tropics, well-developed, physically and mentally, living on a simpler diet as regards meat and alcohol.

All carbohydrates are converted into glucose before absorption, and in this form are more readily metabolised than fats or proteids. Owing to the ease with which they are oxidized the carbon is easily liberated for the purposes of energy, and with less production of internal heat than with the two latter. For this reason they are most valuable food-stuffs for the production of energy in the Tropics, as they impose less labour on the organs of digestion. The cereals indigenous to the Tropics, such as maize, rice and the native lentil, are also to be preferred.

When energy is to be liberated rapidly with the least tax upon the digestive system, sugar, an almost pure soluble carbohydrate, is an excellent food for the purpose. It is a proteid sparer being rapidly oxidized. Sugar has long been given to racehorses to increase their energy. Mosso first demonstrated that sugar lessened fatigue. Vaughan Harley showed that it was a rapid provider of energy with which extraordinary muscular exertion could be made.

In the Philippines the cavalry horses imported from America became emaciated and refused to eat, until it was discovered that molasses or sweetened water sprinkled on the coarse grass or hay made it palatable. When thus fed they grew fat and sleek.

Among the troops engaged at Porto Rico and the Philippines, whose appetites had become impaired, there was a craving for candies and sweets, which was relieved by a supply of these articles. Experiments have shown that the fatigue of cyclists on long record-breaking trials has more quickly been relieved by sugar than by other foods. Sweetmeats, or such fruits as dates, grapes, bananas, figs, and prunes, which contain with their sugars acids and extractives, may be used.

An ordinary lump of sugar weighs about 5 grams, so that it is capable of yielding about 20 calories. The large share which sugar takes in the diet of the inhabitants of warm climates is a very noticeable feature. Sweetmeats in every shape and form enter largely into the diet, and presents of sweetmeats and fruits correspond with presents of game in colder climates. The most digestible sugars are the glucoses, of which dextrose or grape sugar, lævulose or fruit sugar, and invert sugar a mixture of dextrose and lævulose as in honey, are the chief forms.

The common defect in the diet of rice-eating populations is a deficient proportion of nitrogenous matter, and an over-bulkiness of carbonaceous matter.—Rice-eating populations are often ill-nourished and weakly because of the small proportion of nitrogenous matter in the rice. Unless other food-stuffs be added which are rich in proteids, fats, and mineral ingredients, the rice, though agreeable and digestible, is deficient in nourishment, and is apt to cause anæmia and symptoms of scurvy. New rice is not as wholesome as old rice, and rice which has been sown on swampy ground and has not been transplanted, and which comes to maturity at the close of the rainy season, frequently causes diarrhœa and

general intestinal disorder. Even the best rice is deficient in phosphoric acid, lime, and other mineral matters, as well as in nitrogenous matters. In grain-eating populations the starchy constitutents are also likely to bulk too largely in the diet, and require to be corrected by the addition of a little animal food rich in fat, such as eggs, which it will have been noted contain about 12 per cent. of fat, and 12·5 per cent. of proteids, or of seeds rich in proteids and oil, such as the ground nuts or soy beans, which contain respectively about 50 and 19 per cent. of oil, and 24 and 35 per cent. of proteid, or by adding other pulses less rich in oil and supplying the requisite amount of oil separately. Fresh vegetables may be added to the rice to make up for the deficiency in mineral matter. Excess of starchy and fatty foods causes dyspepsia, acidity and flatulence, delays nitrogenous metamorphosis, and produces excess of fat and corpulence. If disturbed nutrition follows the excess of sugar and starch it may lead to a chronic form of diabetes.

Diseases caused by Food.—In addition to ill-health produced by excess or insufficiency of food, disease may result from a lack of one or more of the principle constitutents or by decomposition, alterations or a diseased state of the food itself.

Scurvy.—Whenever there is a deficiency in vegetables and fruits in the diet the fluids of the body tend to become less and less alkaline and scurvy is likely to appear. The cause has generally been ascribed to a deficiency in the supply of potash or of the organic acids.

It is still a question, however, whether scurvy is primarily caused by the absence of fresh vegetables in the food. Facts seem to strengthen the opinion that the absence of fresh vegetables will not in itself produce scurvy. Communities have been known to live without them, and yet to be free of the disease. As pointed out by Captain Jackson and Vaughan Harley, scurvy is generally associated with salted meat or fish, that is, with

meat or fish that is generally insufficiently preserved; in which case the decomposition which goes on gives rise to ptomaines, which are unaffected by the cooking to which the meat or fish is subjected. It is perhaps these ptomaines which produce the conditions giving rise to scurvy. The partaking of vegetables in the food with the acids and salts they contain, probably counteracts the effects of the ptomaines or lowers the quantity of them that is taken, and thus exerts a protective influence.

Wright attributes scurvy to a deficiency in the diet of "alkaline" foods leading to a diminution of blood coagulability. Alkaline foods are those the ash of which is alkaline in reaction, such as carrots, turnips, potatoes, onions, milk, peas, lemon juice, orange juice, beans, &c.

Scurvy is likely to occur in damp low-lying localities, in which the soil is strongly impregnated with salines, chiefly nitrate of potash, or in arid regions where cultivation is impossible. It is to be met with in India, Central and South Africa, parts of China, Central Australia, and Japan. In scurvy there is intense general debility and certain chemical changes in the nature of the blood, causing effusion and hæmorrhages into the tissues, with swelling of the joints. The gums become swollen, spongy and ulcerated, the conjunctivæ pearly, and the aspect sallow. The disease is accompanied by dysenteries and foul ulcers. The prevention consists in the supply of fresh meats, fruits and vegetables. All anti-scorbutic diets contain a large amount of vegetables, with a large proportion of potash salts. The orange, lime, melon, apple, prune, tomato, and grape, potato, yam, cabbage, and other green vegetables, are especially useful as anti-scorbutics; yams are useful; they are valuable for the organic acids and mineral salts they contain, especially the salts of potash. The ash of wheat flour, or bread is formed of acid phosphates, while that of peas, beans, haricots, cabbages, &c., cauliflower, lettuce, spinach, celery, brussel sprouts and turnips, is strongly alkaline. Dried vegetables are anti-scorbutic, but less so

than when fresh or preserved. Lemon or lime juice, 1 oz. daily, is efficient. One fluid oz. of lemon juice contains 30-40 grains of citric acid. The citric acid and citrate of potash are oxidized into carbonic acid and alkaline potassium carbonate. The juice of the cashew nut fruit made into a drink is an excellent anti-scorbutic. Vinegar, ½ to 1 oz. daily, is a poor substitute. Alcohol is not an anti-scorbutic. Wright advocates 20 grains of Rochelle salt with 5 grains of crystallized calcium chloride as a prophylactic.

Rickets, a disease among infants fed on artificial foods, which are more or less starchy in their nature, and deficient in some of the elements which make up a complete food, does not occur among infants fed exclusively on milk, which contains the necessary amount of fat, lime and phosphate in an assimilable form.

Effects of unwholesome Grain.—The general causes of unwholesomeness of food is either decomposition or a diseased condition of the food. When grain is decomposed and mouldy, which happens after it has been submerged or has been lying in a damp place, it is unwholesome, producing intestinal irritation, colic, diarrhœa, and other symptoms of poisoning. Mouldy or sprouting grain should always be condemned as unfit for human food. It is recognized by the discoloration of the grain, a musty odour, and, if well advanced, by adherence of the grains to one another. The microscope will detect moulds.

Apart from intestinal disorders and illness produced by decomposed and mouldy grain, there are four specific diseases attributed to grain poisoning owing to an altered condition of the grain either when in crop, or afterwards. They are beriberi, pellagra, lathyrism, and ergotism. They resemble one another in producing nervous affections, but the three last are the most closely allied in their symptoms, attacking particularly the spinal cord, each appearing to have a selective affinity for a special part of the structure of the cord.

Beriberi.—Rice which has become mouldy, decomposed and damaged is believed by many to be the cause of beriberi where this disease is endemic. Whether the actual agent of the disease is a toxic-producing microbe or fungus that has developed in the rice during the time of storage only, or is as W. L. Braddon[1] thinks a poison generated by some rust fungus, microbe ferment, mildew, or mould often, or commonly growing on and gathered with the crop, which parasite is able to continue to multiply in the grain or glumes when stored and especially when damp or decayed, is still a matter of speculation and can only be determined by careful investigation. Braddon is of opinion that the beriberi poison is probably an alkaloid which is stable and non-volatile and resembles atropine and muscarin in some of its effects. There are many facts in favour of the rice theory, some authorities, however, maintain that the causation of beriberi is due to an unknown microbe or protozoon not dependent on rice as a vehicle to invade the body, and that the endemicity or prevalence of the disease in regions where the majority of the people are rice eaters is merely a coincidence. Dr. Daniels is disposed from his investigations to think that beriberi is an infectious disease due to a protozoon transmitted from person to person by means of a pediculus which acts as an intermediate host. Experiments made by Hunter and Koch in Hongkong on monkeys infected with blood from persons suffering from beriberi failed to produce the disease showing, at least, that no bacterium causing beriberi exists in the blood. The experiments would not, however, exclude the presence of a protozoon, if an intermediate host were needed for its development. Professor R. T. Hewlett and Dr. W. E. De Korté are of opinion that the causal agent may be a protozoon which is eliminated by the kidney. The bacterial theory pro-

[1] "The Cause and Prevention of Beriberi," by W. Leonard Braddon, M.B., 1907.

pounded by Hamilton Wright of a micro-organism which is swallowed and multiplies in the duodenum and alimentary tract and there elaborates its poison is not necessarily under all circumstances opposed to the rice theory. Indeed, it may fit into it as well as the water theory in regard to cholera, for although water is known to be the chief channel for cholera infection by the comma bacillus, there are other avenues or media by which the infection may reach the intestinal tract and cause an outbreak.

A fungus or germ which forms a toxin in the affected rice outside the body and which is capable by its prepared toxin alone, even when the fungus or germ is destroyed by cooking, of producing a beriberi peripheral neuritis when swallowed is not unlikely to be able to gain access under certain circumstances into the intestinal canal without reference to mouldy rice, prepare its toxin there, pass out with the excreta, and then spread by defective sanitary conditions more particularly connected with the disposal of the excreta. Such a mode of spread might also happen where only the first cases were caused by mouldy or infected rice when the microbe or fungus is still alive, and when overcrowding increases the chances of infection. It is a curious fact pointed out by Braddon, that in the Malay States the Malays, who consume cured rice, *i.e.*, rice which has been steamed or boiled, then dried and afterwards husked, before storage, do not suffer from beriberi, while the Chinese who consume uncured rice, *i.e.*, rice that is simply husked, suffer from the disease, but that when the Malays are placed under the same conditions as the Chinese—as in jails and asylums—and consume uncured rice they in common with the Chinese are subject to beriberi.

Fletcher[1] gives a very instructive experiment which he carried out in the Kwala Lumpur lunatic asylum

[1] Rice and Beriberi, by Wm. Fletcher, B.A., M.B., B.C.Cantab., *The Lancet*, June 29, 1907.

during the year 1906, in which he placed half the number of patients on cured or Bengal rice and half on uncured or Siamese rice, with the result that amongst 120 inmates on uncured rice there were forty-three cases of beriberi, two of which were admitted with the disease, and of these eighteen died, whilst amongst 123 inmates on cured rice, there were two cases of beri-beri, and both of these had the disease on admission.

In order to test the influence of place infection, the two groups were transposed, those inmates on cured rice being transferred to the wards previously occupied by those on uncured rice and *vice versâ.* Notwithstanding the change, no case of beriberi occurred among the inmates on cured rice, although they were living in a ward where beriberi had been rife among the inmates who were fed on uncured rice. One of the most striking instances of the connection between rice and beriberi is that afforded by the Japanese navy. Before 1883 at least one quarter of the men were affected with beriberi. In 1884 Baron Takaki determined to alter the diet. For a portion of the rice he substituted meat, and for another portion barley, thus reducing the 26 or 28 oz. of rice to some 7 oz. The result was remarkable. In three years, beriberi practically disappeared from the navy. There were some sanitary improvements carried out in the ships which made them drier and put them into a more hygienic condition. Doubtless these general measures assisted in preserving in a better condition the smaller amount of rice used, but there can be little doubt that the main cause was the change in diet. Takaki himself attributes the causation of the beriberi to a rice diet which was deficient in nitrogen, which was remedied by the meat and barley—though nitrogen starvation would hardly occur unless there was something wrong with the rice, whereby the relatively small amount of available nitrogen was still further lessened by being combined in a form

injurious to the system.[1] No chemical analysis of rice which has been subjected to the destructive action of insects, moulds and the various micro-organisms abundant in a damp and infected store, has yet been made. But the fact that the change of proteids caused by the ordinary digestive ferments and different intracellular enzymes gives rise to certain crystalline and nitrogenous waste products, which in excess act as toxins to the system, would favour the view that the proteid of rice when stored under certain conditions is attacked, the result of which is that in some cases a part of the nitrogen enters into other combinations forming toxins.

The supply of fresh meat and barley not only reduces the quantity of rice taken and thereby the amount of toxin consumed, but, probably, as in the case of scurvy, it provides some extractives or salts which neutralize the toxin.

No one who has seen the storage of rice where beriberi is endemic, and the kind of rice which some of the poorest class eat, can fail to be impressed with the facts that have been gathered as to the relationship between rice and beriberi, although that relationship probably does not cover the whole epidemiological problem connected with beriberi. Rice is the staple food in the Tropics as wheat is in Europe, and it is interesting to note that Nocht, of Hamburgh, has met with a number of cases of peripheral neuritis, which he names pseudo-beriberi, associated also with cases of

---

[1] Rosenheim and Kajiura have found that proteins constitute only about 7 per cent. of rice. The proteins are rice-globulin, rice albumin, and oxyzenin (an alkali-soluble protein). An alcohol-soluble protein is practically absent, hence probably the unsuitability of rice for bread-making—for which purpose both alcohol-soluble (gliadin) and alcohol-insoluble (glutenin) proteins appear to be necessary. The alcohol-soluble proteins or gliadins of other cereals are characterised by their high percentage of glutaminic acid among their cleavage products. This may have some bearing on the etiology of beriberi (*Proc. Physiolog. Soc.*, January 25, 1908).

scurvy, on board certain ships in which flour had been substituted for biscuits, and in which the bread made from the flour was unsatisfactory owing to the flour having been mouldy.

The precautions to be taken against beriberi in an institution in the endemic area, are to provide rice that has been treated in the Indian and Ceylon fashion before husking, to see that it is free of moulds and that it is kept in stores that are thoroughly dry, and that the stores are free of insects and vermin and are thoroughly well ventilated. Stores as a rule in the Tropics are kept in a filthy and damp condition, and act as incubating chambers for fungi, microbes, and insects. They should be periodically cleansed and disinfected. The mode of disinfection will be referred to later (p. 151).

Pellagra.—Maize or Indian corn when decomposed or damaged is said to produce pellagra which is a general non-febrile disease accompanied by a skin eruption. Sandwith defines pellagra as a "chronic, endemic, non-contagious cerebrospinal disease of poverty-stricken peasants. It produces changes in the brain, spinal cord, tongue, and intestines; sometimes ends in melancholia and dementia, and causes chiefly in the summer months an eruption on those parts of the skin exposed to the sun." In pellagra the posterior columns and lateral pyramidal columns are affected with sclerosis, and the symptoms partake of both conditions.

The eruption begins as an erythema, not unlike a severe sun-burn. It is very symmetrical on the forearms and legs. The primary erythema disappears by desquamation, and leaves behind it patches of roughness, or what is considered chapping. These attacks will come on periodically, leaving behind a greater roughness, with at first hypertrophy and later atrophy of the affected skin. In addition to the skin eruption there is usually diarrhœa, denuded tongue, altered knee-jerk, tenderness near the dorsal vertebræ, and melancholia or dementia. Pellagra is common in Italy and in Egypt, where the

poorer people live on damaged maize. Sandwith records that in some districts of Italy more than 5 per cent. of the inhabitants are pellagrous, and he shows that the disease is common in lower Egypt where maize is eaten and rare in upper Egypt where millet is the staple food. He also points out that cases have been recognized in India, South Africa, and South America. The symptoms have been ascribed to the action of fungi or bacteria, or of the toxins manufactured by one of these while the grain has been stored in damp places. The actual germ or toxin has not been isolated with any degree of certainty. Lombroso found in pellagrous maize two toxins one alkaloidal like strychnine, the other like hemlock, the administration of which produced pellagrous-like symptoms. Spirit made from unsound maize appears capable of producing the disease. Similar toxins were found by Haussmann and Cortes. Ceni attributes the disease to the *Aspergillus fumigatus* which has been found in damaged maize associated often with *Aspergillus flavescens*, and *Penicilium glaucum*. The *Aspergillus fumigatus* has been discovered in *post-mortems* made on pellagrous subjects, also in the excreta of men suffering from peliagra, and during life in that of poultry fed on bad maize, and on death in their lungs and intestines. For purposes of prevention maize from pellagrous districts should not be allowed to be imported into healthy districts, and in all pellagrous districts a very careful supervision should be exercised over the places where maize is stored, and before storage the grain should be thoroughly dried. Damaged maize should be destroyed.

Lathyrism.—Certain crops of the *Khesari dal* or *Lathyrus sativus* cause lathyrism, which is believed to be a disease of the lateral pyramidal tracts of the spinal cord.

The Khesari dhal or *Lathyrus sativus* is a vetch used as a grain food, mixed often with other grains. It produces in too large quantities dyspepsia, colic and constipation, and when habitually eaten in large quantities, paralysis of the legs. This occurs more

particularly at famine times when unusual quantities are eaten. The poisonous principle is believed to reside in the grain itself, and thus differs from the alteration produced by a fungus growing in the grain. It is thought to be a volatile alkaloid which can be destroyed by thorough cooking, but neither of these views is completely established, as in the case of rye, causing ergotism. The poisoning produced by the *Lathyrus sativus* in India still needs further investigation, for the same plant grown elsewhere out of India, and even in some parts of India itself, when largely consumed does not produce the disease.

The occasional use of this pulse, or its use along with other food grains, is seldom injurious, though it may produce colic and dyspepsia, but if freely used and for a long period it causes paraplegia. The onset of the disease is usually sudden, preceded perhaps by indigestion, colicky pain, and diarrhœa. The muscles of the lower limbs become affected and paraplegic ; the trunk and upper limbs remaining unaffected. The patient has a peculiar gait, the leg with the toes pointed is thrown out in tremulous extension and adduction, the toe reaching the ground before the heel, or the heel does not reach the ground, the gait becoming a tripping one on the toes. Paralysis is produced in horses and cattle as well as in man by the too liberal use of the grain.

The consumption of rye which has been attacked by the fungus *Claviceps purpurea* produces ergotism. The symptoms of ergotism depend on two factors, viz., sclerosis of the posterior column of the spinal cord similar to that in locomotor ataxy; and stimulation of the vaso-motor centre in the bulk. There is voracious appetite, loss of sensation, pain, tingling and creeping, arterial spasm, high blood pressure, coolness and insensibility of the extremities, small and imperceptible pulse, convulsions and gangrene. The egotized rye may have been eaten by itself or mixed with flour. The ergot is the condensed mycelial growth—termed the

sclerotium—of the fungus in the rye grains. This lies dormant during the winter. In summer, the mycelium grows at the expense of the grain and throws off its conidia. Later, the mycelium in the outer part hardens, forming the horn-like case, the whole forming an ergot which is distinguished from the normal rye grain by being larger, of a dark brown or violet colour, and having a disagreeable odour and bitter taste. This is the resting stage. Later, the ergot falls to the ground, and in the spring when exposed to moisture the sclerotium sprouts, and sends out a number of club-shaped growths of a purplish colour with white stems. These club-shaped growths are the fungus *Claviceps purpurea*. If a section of the spherical head of the fungus is made, it will be seen to be packed in the inner surface with perithecia containing cylindrical ascospores, which swell under the influence of moisture, and which, when ejected into the open air, attach themselves to the pistil of the flower. Their germination begins afresh under favourable conditions, mycelia and gonidia being formed.

Wheat like rye, is also subject to parasitic growths destroying the ear and the grain, but hitherto no distinct illness has been ascribed to the use of flour containing such diseased grains. Nevertheless, wheat of this kind should always be destroyed and not permitted to be used for human food. The most common parasites attacking wheat are those belonging to the two families, the *Æcidiomycetes* and *Ustilaginæ*, producing what are commonly known as rust or mildew, bunt and smut. The rust or mildew of wheat is caused by the *Puccinia graminis* which belongs to the *Æcidiomycetes* and which attacks the glumes of wheat. The bunt and smut belong to the *Ustilaginæ*. The bunt is caused by the *Tilletia caries*, called also the *Uredo fœtida*, which gives the grain an offensive smell and attacks the interior of the grain reducing it to a black and smeary powder. The spores are round and light brown in colour with a reticulated surface. "Smut" is caused by the *Uredo*

or *Ustilago segetum*. It gives a black colour to the ears of wheat attacked and fills up the interior of the grain with small round and brown spores the surface of which is smooth. The smaller size of the smut spores and their smooth surface distinguish them from "bunt."

The three groups of insects that are most destructive to grain are the weevil or Calandra, the Tribolium, and the alucite. They deposit their eggs in the grain before or after harvesting. The principal weevil in the Tropics is the reddish-brown *Calandra oryzæ* or rice weevil; it attacks all kinds of stored grain such as maize, rice, buckwheat, beans and peas. By means of its proboscis the female pierces a hole in the grain and then lays an egg in it. The larva hatched from the egg consumes the contents of the grain, then enters into the pupa state for a few days, and finally, develops into the insect which leaves the grain and undergoes its full development in some hidden part of the granary. The larva of the weevil is white, about $\frac{1}{4}$ centimetre in length, with a yellowish head and a body of nine rings. The metamorphosis from the deposition of the egg to the fully developed weevil varies according to the temperature, being longer in cold countries and shorter in the Tropics. In the latter it may take about one month to six weeks. The fecundity of the weevil is so great that it is a most destructive insect, sometimes 50 to 75 per cent. of the rice or maize being damaged. Unless in very great abundance, weevils are not easy to find, they dislike light and noise, hide themselves, and are seldom to be found on the surface of the grain. They attack with avidity grain which has been badly harvested and not thoroughly dried, particularly when the temperature is favourable. The larva of the *Tribolium* is whitish, longer than the larva of the weevil and has a brown head which is scaly and armed with curved sharp mandibles. The caterpillar of the alucite spins a gauzy veil over the grooved part of the grain and then proceeds to eat its way into the grain, where it remains feeding on the

grain until this becomes a mere shell. The damaged grain gives way under pressure of the fingers and when thrown into water floats.

The *Acarus farinæ* is an insect which is frequently found in flour. Its presence usually indicates decomposition. A microscopical examination of the flour, especially any portions of it which feel moist and are discoloured, usually shows besides the acari, micro-organisms and moulds indicative of fermentative changes.

Anguillulæ or *Vibriones tritici* (*Tylenchus tritici*) are found in wheat grains, and give rise to the condition known as "ear cockle." They are usually met with in grain kept in damp places, and may be suspected by the small size of the grain and its dark discolourations. If the affected grains are steeped in water for an hour or two and then examined under a low power objective, small worms, about ·6 to 1 mm. long, will be observed.

The preservation of grain in Europe if for a long time is effected with difficulty unless in cold stores maintained at the low temperature of 10° C., at which insects that feed on the grain and microbes do not multiply. In the Tropics the difficulty is increased by the high temperature and often by the dampness of the climate. Rice, maize, peas and beans may be preserved by disinfecting the stores, warehouses and granaries once every six weeks or two months with 2 per cent. of SO_2 gas, keeping the store closely sealed for four or five hours, by which time the percentage of SO_2 will have been reduced to less than half per cent. by absorption. The most effective mode of carrying out this fumigation is by a portable Clayton machine, A type. This will destroy rats and mice, insects, their eggs and larvæ, and to a large extent fungi and microbes.

All "gunny" bags should also be disinfected at the same time, because once they are infected they will infect fresh grain put into them. All holds of boats and ships carrying grain, whether in bags or in bulk, should be thoroughly fumigated before the grain is put into them, and also again when the grain is removed.

Stores also should be regularly cleansed and kept quite dry. When fumigation by Clayton's apparatus is not attainable, much may be accomplished by keeping the stores clean, while the ravages of insects and the effects of fungi may be lessened by frequent turning over of the grain, exposure to the sun, and storing it in thin layers.

Milk also undergoes change when kept, and has in some instances given rise to nausea, vomiting, dryness and constriction of the fauces, burning sensation in the œsophagus, diarrhœa, cramp, and collapse. Outbreaks of this kind have occurred in America and India, and similar outbreaks have been traceable also to decomposed cheese, and to ice creams. The researches of Professor Vaughan, of Michigan University, have shown them to be due to a benzene derivative formed in the cheese and milk by decomposition, which has been named lacto-toxin or tyro-toxicon. The tyro-toxicon has been isolated in the form of needle-shaped crystals, which give a blue colour with potassium ferricyanide and ferric chloride.

Milk becomes sour rapidly in hot climates, and more rapidly if the cow is diseased. Milk exposed to sewer gas absorbs the gas readily and soon decomposes. Upon distillation it yields an offensive and poisonous liquid, causing headache and diarrhœa.

There are specific diseases in which infected milk plays a special rôle in their dissemination in the Tropics. These are Malta fever, cholera, typhoid fever and dysentery. Tuberculosis is not an important disease among milk cows in the Tropics. Malta fever, caused by the *Micrococcus melitensis* discovered by Bruce in 1887 in the spleen of cases of the disease, has since that time been differentiated from typhoid fever and malaria with which it was often previously confounded. The discovery, enabled those investigations to be undertaken later, by the Malta Fever Commission which, among other important facts, ascertained that the micrococcus of Malta fever

is present to the extent of at least 10 per cent. in the milk of many Maltese goats without the animals themselves suffering from any special symptoms. The boiling of the goats' milk has produced a very marked reduction in the prevalence of the disease among soldiers at Malta, especially among the officers who previously, owing to their consuming more milk than the soldier, suffered an incidence of the disease three times greater than the latter.

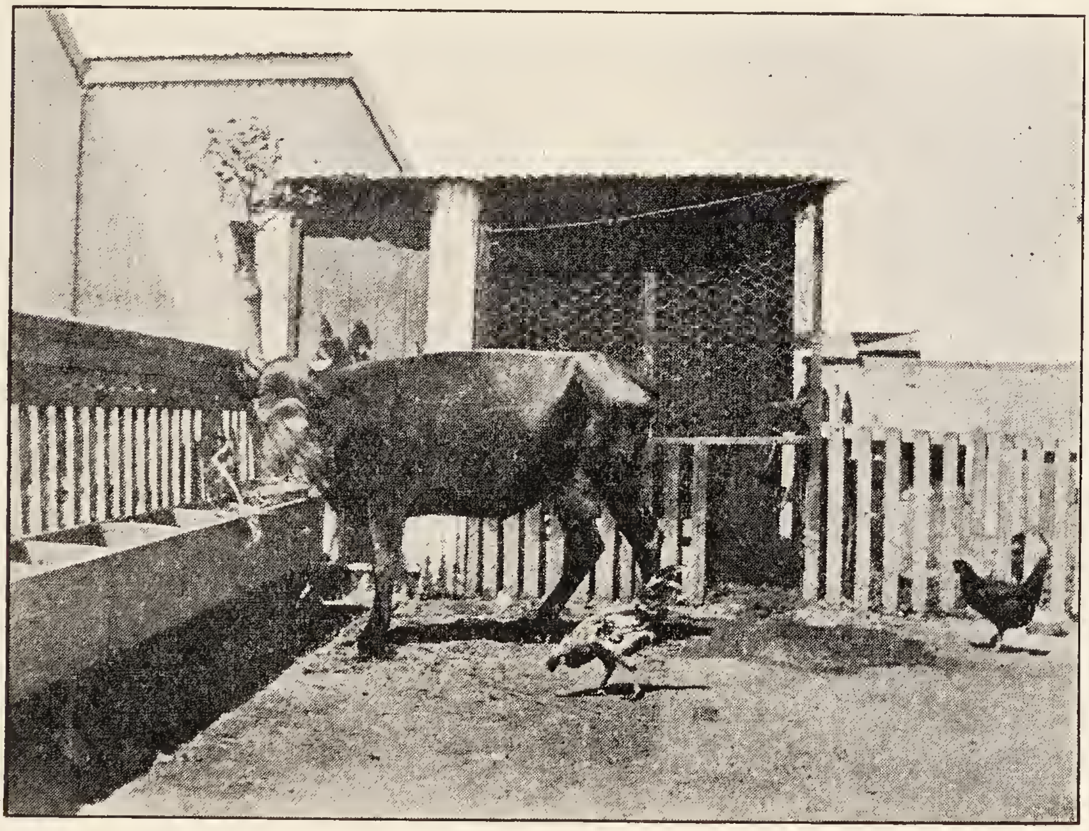


FIG. 20.—A milk-seller's yard. Privy behind cow-house on right. Surface drain passes across neighbour's yard.

Cholera was shown by Simpson in 1887 to be spread by infected milk under the following circumstances. An outbreak of cholera occurred simultaneously on board ship, the *Ardenclutha*, lying in the Hooghly at Calcutta, and in a distant village from which it was ascertained the crew obtained their milk. Investigation demonstrated the fact that the drinking water tank in the village had been polluted by the discharges from a recently imported case of cholera, and that as a result there was

an outbreak of cholera among those who drank the water; further, it was ascertained that the milkman who supplied the *Ardenclutha* crew with milk had diluted it with water from the specifically polluted tank, and that only those of the crew who drank the milk were attacked.

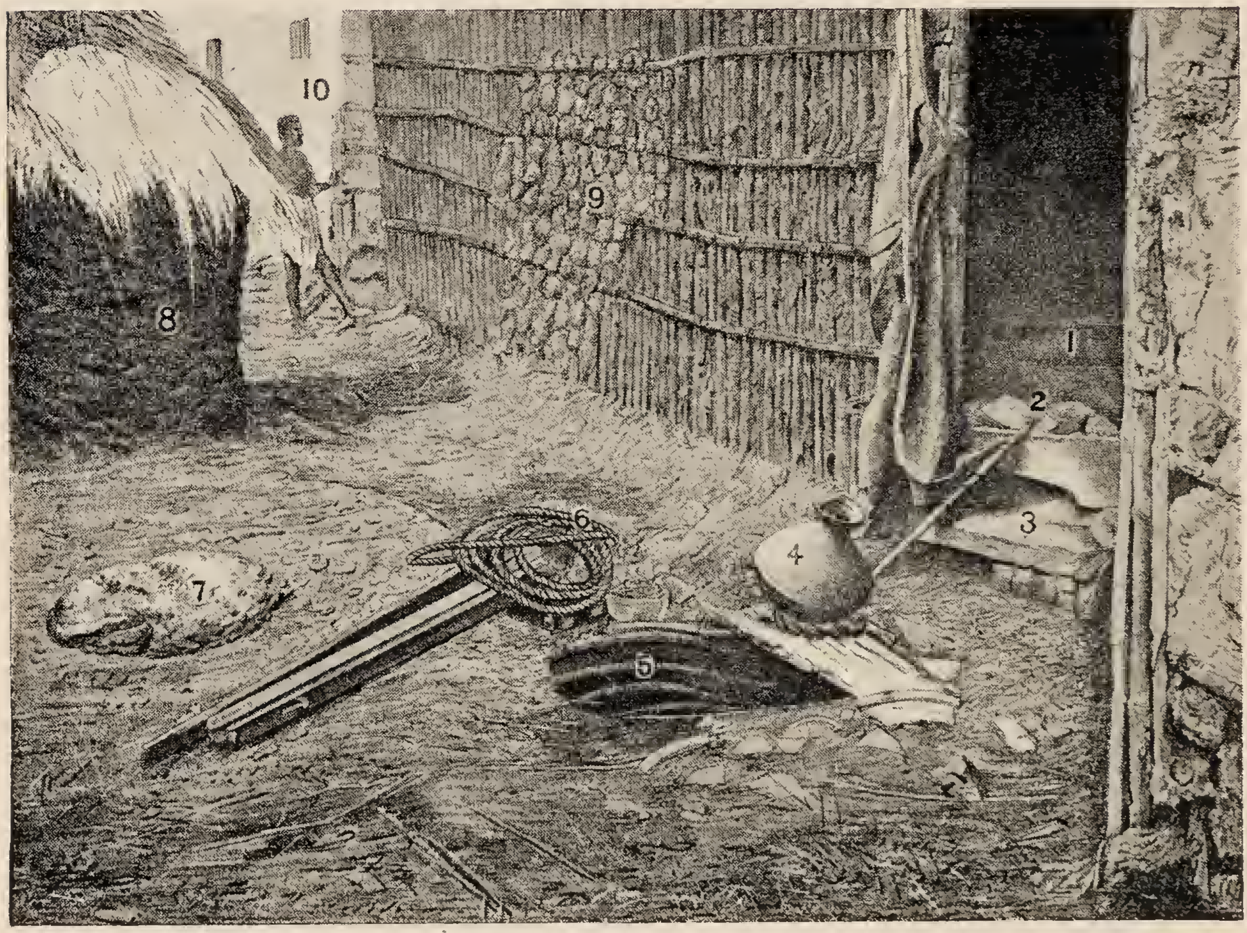


FIG. 21.—Photograph of milk-seller's premises and cow-shed. (1) One of the feeding vessels; (2) broken condition of cowshed floor; (3) steps at entrance of cowshed; (4) chattie standing on board lying across opening of well; (5) well; (6) rope used at well; (7) mass of semi-fluid cowdung; (8) stack of cowdung; (9) cowdung cakes plastered on wall; (10) latrine.

Since then several epidemics have been traced to milk and the comma bacillus has been found in the milk.

Typhoid fever and dysentery among Europeans in the Tropics are frequently traced to the adulteration of milk, or to the very insanitary method of handling the milk, and cleansing of the milk utensils. There is scarcely anything more dangerous than the drinking of unboiled milk in the Tropics. Apart from the usual filthiness of

the cowsheds, the water on the premises is generally from a shallow well unprotected from the surface drainage (fig. 20). The water is raised as a rule by buckets that have been standing amidst filth and mire, and the platform of the well, if there is one, is used for bathing purposes (fig. 21). There is seldom any special arrangements for keeping the dairy utensils in a clean place, or for thoroughly cleansing them. Scrubbed out with mud and straw and then rinsed they are, if not left in the cowshed, often put into the dwelling hut along with domestic vessels, a favourite place being under the bed, which is a general store for dirty utensils, &c.

No milk should ever be taken in the Tropics unless it is boiled, or unless the cow is brought to the door and milked in the presence of the buyer into a clean vessel, provided at the time by the purchaser of the milk. Even this precaution is insufficient in the case of goats' milk, which should always be boiled.

Klein's Method of Isolation of Bacillus Typhosus in Milk. Enrichment Method.—Demonstration in milk is extremely difficult by ordinary methods, and by Drigalski's medium, chiefly on account of the very numerous bacteria, inclusive of those of the coli-type, present in ordinary milk (*vide* amount of stable dirt present in milk). Milk such as is bought in the London shops of good character contains from 100 to 1,000 *Bacillus coli* per 1 cc.

It is, therefore, of great importance to allow enrichment of *B. typhosus*, if such be present originally in very small numbers, and therefore not capable of demonstration by the ordinary methods. Malachite green added to milk allows such enrichment. The method which was found to answer is: to each 100 cc. of the milk add 0·0625 grams of *sodium taurocholate* [make a strong solution of *sodium taurocholate*, 6·25 grams in 100 cc. of distilled water, boil. Ten cc. of this solution contain 0·625 gram of *sodium taurocholate*] and 6·6 cc. of a 1 per cent. aqueous solution of Löffler malachite green (120 *Höchst*); this would make malachite green

1 in 1600, 7·15 cc. of same malachite green solution added to 100 cc. milk would make malachite green 1 in 1500. After incubation for 24-48 hours at 37° C. of the milk make Drigalski plates.

A not uncommon source of illness among native populations in the Tropics is the keeping of food which has been cooked over night, or in the early morning, for meals of the next day. This is done to save fuel. The result is often that the food becomes decomposed, or from long standing amidst insanitary conditions absorbs or has added to it foul emanations or infectious material. The cooking utensils may also add injurious substances to the food. This may occur by cooking acid substances in copper pots or in utensils which have been lined or soldered with lead instead of tin. Food ought not to be prepared in either leaden or copper vessels. Some glazes of earthenware utensils also contain much lead, which may go into solution.

Meat which is perfectly good decomposes very rapidly in the Tropics, and on account of this is not kept long, but is eaten quite fresh. It is generally cooked and eaten the same day that the animal is killed. Putrid meat is easily detected by its smell, by its pale and, later, greenish colour, and by the offensive odour it gives off if cut up into small portions and put into hot water ; by adding to the boiling water freshly prepared lime water, a peculiarly offensive ammoniacal smell is given off. Great care should be taken in the storage of meat either cooked or uncooked. The store should be clean, with sanitary surroundings, and the meat, under every circumstance, should be protected from flies, mosquitoes, and other insects.

Characteristics of Good and Fresh Meat.—Fresh and good meat should be firm and elastic to the touch not pitting on pressure, of a good colour throughout, florid in young animals, and darker in older ones, but never dark red, livid, mahogany, magenta, or very pale in hue. The colour should be uniform, and not patchy. There should

be such an intermixture of fat as to give the meat in most parts of the carcass a more or less marbled appearance. The colour of the fat varies from white to yellow. A knife or skewer plunged into the meat should be offered an even resistance, variation in this respect indicating the presence of either cavities due to abscesses, or softening due to commencing decomposition. The appearance and smell of the knife when withdrawn will be a guide; in good meat it is sweet. The juice from good meat is reddish, and acid in reaction. If alkaline there will be found signs of decomposition which will manifest itself in a pale colour of the meat, a disagreeable smell, a softening of the tissues, and later a greenish colour.

The flesh of the sheep is less florid than the ox, and the fat is firmer and whiter in colour. As goats are much used in the Tropics, it is desirable that carcasses of sheep should have the feet attached. The flesh of the goat is darker than that of the sheep, has less fat, and when heated gives off a goaty odour. The flesh of the pig is pale, and the fat is somewhat unctuous. All meat should be stamped before leaving the slaughter houses.

Illnesses caused by Decomposed and Infected Meat.—Decomposed meat produces diarrhœa which may assume a choleraic nature. A not infrequent cause of serious diarrhœa, almost indistinguishable from cholera, is that caused by eating fish or brains which are not fresh and have undergone a certain amount of decomposition. It is, however, when meat has been insufficiently preserved that the most serious results are likely to occur from its ingestion. An instance of this happened on board the S.S. *Crofton Hall*, in the Hooghly. After the vessel left the port of Calcutta, meat that had been indifferently salted was served out to the crew, with the result that all who ate of the meat, twenty-three out of a crew of twenty-nine, were attacked with vomiting and purging, accompanied with cramps, and with other symptoms of so serious a nature that six out of the twenty-three sailors died, and the remainder suffered from extreme prostra-

tion, tremblings, and an eruption of boils and carbuncles. Similar symptoms have been produced with tinned meats, the tins of which, from some cause or another, were not air-tight. The ptomaines or poisonous alkaloids formed by the action of the micro-organisms of decomposition on the animal substance, which are not destroyed by cooking, serve, together with the microbes which may escape destruction, to cause these illnesses.

Many outbreaks of meat poisoning have occurred in England. The first of these discovered to be due to infected meat was one which occurred at Welbeck, in Nottinghamshire, where, after eating ham which was afterwards ascertained to have been exposed to sewer air, seventy-two persons were attacked with diarrhœa and vomiting, pains in the abdomen, cramps in the limbs, cold sweats, fever and prostration. Four of the cases ended fatally. Klein isolated from the ham and from one of the fatal cases a bacillus which on culture produced similar symptoms on guinea-pigs and mice.

It is now recognized that most of these poisonings by meat are due to infective organisms of the coli group and their toxins, and that the symptoms produced may vary according to the infecting bacillus and the amount of toxin ingested. More than a score of bacilli of different kinds have been isolated, a large number of them conforming to the Gaertner group. Of these the best known are the *Bacillus enteritidis* of Gaertner which is a non-sporing bacillus and is quickly destroyed at a temperature of 70° C.; the *Bacillus botulinus* of Ermengem which forms spores, and requires an exposure of at least half an hour at a temperature of 80° C. to devitalize them; and the *Bacillus enteritidis sporogenes* of Klein which is also a sporing organism.

The preservation of food is not always an easy matter, and when decomposition sets in it is occasionally accompanied by the production of most offensive gases, while at other times the gases are almost unnoticeable. An example of offensive gases came before me in Calcutta.

Some fresh salmon had been sent out to Calcutta preserved by a new process. The barrel of salmon was sent to the chemical laboratory, and several leading men interested in the subject were invited to see the result. The professor of chemistry began to prepare the lid for opening, but before he had proceeded far in his operation the lid and the contents of the barrel were projected with force up towards the ceiling, and everyone near was besmattered with a most offensive smelling stuff, the smell of which could only be compared with carbon disulphide, and which stuck to everything that was touched by the stuff for at least a week, notwithstanding the most careful washing. The preservation of meat is generally effected by cooking and keeping in sterilized tins, by desiccation, which is usually done in hot climates by cutting up the meat into fine thongs and exposing it to the air and sun, by salting, by smoking, by refrigeration and by freezing. Refrigerated meat, *i.e.*, meat kept at a temperature of 1° C., differs from frozen meat which has been first placed in chambers maintained at 10° to 12° C. and then transferred to others at a temperature of 5° C., in that it does not keep well longer than a month or six weeks. Frozen meat on the other hand will keep good in the cold chamber for six months. Both require to be cooked a few hours after removal from the refrigerating chamber. Antiseptics such as salicylic acid, boracic acid and formol have been tried, but they should be forbidden as each of them is injurious to the consumer.

Examination of Preserved Meat.—Tins which contain preserved meat in them should be more or less concave on the lower and upper surface and should show no signs of bulging. All tins that bulge should be condemned, for it is a sign that the air has not been expelled or rendered sterile, and that decomposition has taken place with the evolution of gas. Tins giving a hollow sound when struck with a wooden mallet should be looked on with suspicion and very carefully examined.

Refrigerated and frozen meat should also be closely examined, especially some of the parts furthest from the surface and nearest the bone, apparently good carcasses being found to be more or less decomposed when cut through at the hip and shoulder. If the pleura has been stripped the carcasses should be seized. There is one advantage in refrigeration which has been carried on for several weeks, and it is that it generally is fatal to cysticerci. When inspecting salted meat the condition of the brine from which it is taken should, if possible, be examined, and evidence of signs of putrefaction should be very carefully looked for in the meat. Cysticerci should also be looked for. Meat partially decomposed, is either neutral or alkaline, it may vary in colour, it has lost its elasticity, tears easily, and unevenly resists the knife.

Inspection of Animals and their Carcasses.—Meat may be fresh and yet unwholesome, through not being derived from a healthy animal. The animal may have suffered from disease, acute, inflammatory, or infectious, or it may have been infested with parasites.

Of the infectious diseases, the most important are pleuro-pneumonia, anthrax, cattle plague, Texas fever, foot and mouth disease, swine fever, actinomycosis, and tuberculosis. It is safer in the Tropics that the carcasses of animals that have suffered from acute, inflammatory, infectious, or chronic diseases should be destroyed and not permitted to be used for food. In addition to these diseases there are the parasitic or cysticercus worms to be found in the flesh of infected animals. Cooking in the Tropics is often defective, and lesions of the mouth and intestinal tract are common, so that consumption of meats from diseased animals is more likely to be a means of transmitting disease than in cold climates.

Inspection of the live animals will often be sufficient to determine whether the animal is suffering from any one of these diseases; confirmation, however, should always be obtained by a macroscopic and microscopic

examination of the tissues and organs after slaughter of the animal; even when the disease is not so advanced as to give rise to specific symptoms, inspection during life will still give valuable information as to animals not being in a good state of health, and it will differentiate those which incur one's suspicion, and need further careful examination from those that are obviously healthy.

Inspection of Live Animal.—The live animal if healthy is well nourished and not emaciated, it has no difficulty in walking, it is clear and bright-eyed, and not dull, it breathes easily and without noise, its breath is free from any offensive odour, its mouth and nostrils are moist and cold and free from any discharge, its coat is smooth, free from eruptions and not rough and staring, and the animal should not be shivering or apparently in pain, it should not be suffering from diarrhœa, and when slaughtered its organs are healthy. High temperature, difficulty of breathing, cough, diarrhœa, emaciation, an eruption on the mouth and tongue, running from the eyes, mouth and nose, and a staggering gait, are symptoms which will indicate that an animal is ill even if the inspector is unable to diagnose the particular disease.

After the animal is slaughtered the most important information is obtainable from the condition of the different organs which should be healthy, but if these have been removed and only the carcass remains, then the chest-wall, pleura, diaphragm and lymphatic glands should be first carefully examined for any departure from the normal. The connective tissues in the flanks, under the shoulders and arms, beneath the diaphragm and above and behind the kidneys should be examined for any dropsical or extravasated condition, and so should the tissues near the bones for colour and odour. The flesh should also be examined for the presence of bladder-like bodies and the lower surface of the diaphragm for any glistening spots, the macroscopic signs of the presence of certain parasites.

Whenever the carcass is ill bled, bile stained and with

patches of extravasation and the internal organs congested, dark coloured or inflamed, an infectious disease may be suspected. In anthrax the meat is dark and dropsical and bile stained, the liver enlarged and softened, the spleen greatly enlarged, and the blood is dark coloured, fluid and extravasated. The characteristic rod shaped and square ended bacillus is found in the blood and pulp of the different organs, such as the spleen, liver and kidneys. In Texas or tick fever the appearance of the meat and organs is much the same as anthrax, but in the blood and organs are to be found the *Piroplasma bigeminuma* instead of the anthrax bacillus. The *Piroplasma bigeminum* occurs as a pair of small rounded or pear-shaped bodies inside the red corpuscles; they measure from 2 to 4 microns in length by 1·5 to 2 in their broadest part.

In Pasteurellosis the intestinal tract is much inflamed and marked with hæmorrhagic extravasations and the lymphatic glandular system is very much congested and in a hæmorrhagic condition. Microscopic specimens of the pulp from the glands and organs contain a small diplococcus surrounded with a capsule.

In swine fever which is also called swine typhoid, swine typhus, pneumo-enteritis, hog cholera and red soldier, there is a general or patchy redness of the skin which extends through the fat to the flesh. The intestines are inflamed and the larger are affected with ulcers, punched out and covered with ochre-coloured crusts. The lungs are congested and often are affected with lobar pneumonia. Sometimes the lung affection is absent, and sometimes the ulcers in the intestines, and occasionally both are absent, the only sign being the deep reddening of the skin which extends to the underlying fat. The flesh is flabby, pale and wet, and often smells offensively.

In rinderpest no specific micro-organism has yet been isolated. In the early stage nothing is very noticeably wrong further than abrasions of the mouth and tongue, and congestion with cheesy-looking deposits on the

throat and nostrils. Later in the advanced stage the flesh is dark, has a disagreeable smell and may crackle when pressed owing to the presence of air, all the organs are congested in patches with extravasations upon them, and the intestinal tract is ulcerated. The lungs are also congested and emphysematous.

In pleuro-pneumonia the flesh is dark coloured, the lobules of the lung are in different stages of hepatization and surrounded by yellow bands of fibrous lymph. When cut into the lungs give out a glairy liquid, and the tissue is readily torn. The solid portions of the lung sink in water.

In tuberculosis the lungs may be studded with small tubercular nodules, or contain caseous masses, the bronchial glands are enlarged and diseased, and numerous tuberculous nodes called grapes are attached to the pleura, and may be seen also in the peritoneum, liver and kidneys. If the organs should have been removed and disposed of before inspection of the carcass, the pleura is also generally removed to conceal evidence of disease. In this case the diseased condition may be recognized by the flesh underlying the pleura being moist, soft, and often discoloured, and the lymphatic glands being in different stages of enlargement, congestion, extravasation, softening, caseation and calcification, instead of being moist and firm, and of a pale greyish yellow colour as they are in a normal and healthy state. The unhealthy condition of the lymphatic glands in the chest wall will probably be repeated in other parts of the carcass where lymphatic glands are to be found, for instance in the lumbar glands, behind the fat of the kidneys, the sacro-lumbar and the mammary glands.

The tubercle bacilli should be sought for in the glands. In the pig they are not easy to detect.

In actinomycosis which is caused by the Ray fungus or *Streptothrix actinomyces* the lesions are those of an infective granuloma, which generally appear in the form of tumours and ulcers in the upper and lower jaw, and an

interstitial inflammation of the tongue which, from its hardness, is named "wooden" tongue. The tumours may also be found in the nasal cavities, œsophagus, trachea and lungs, and also in the intestines. On section they present a honeycombed appearance, the meshes consisting of bands of tissue within which are fungus tufts and yellowish pus. By examining this spongy material under the microscope the clubs of the fungus will be generally seen to be arranged in rosettes.

The ray fungus is said to grow on cereals, and especially barley. It is believed to infect the animal through a wound in the mucous membrane caused by the awns of barley, when eaten, or by some other accidental mode of inoculation.

Crookshank who worked out the pathology of this disease in animals showed that it was specially prevalent in river valleys, marshes, and on land reclaimed from the sea.

Meat in the Tropics is liable to contain bladder-like cysts called cysticerci. These are but one of the stages in the development of tapeworms which require different hosts for their alternating generations. The cyst when swallowed, as may be the case in infected meat only half-cooked or in a raw condition, undergoes in the small intestine a metamorphosis and develops into a tapeworm. The two most important tapeworms originating from these cysts are the *Tænia saginata* and the *Tænia solium*. The *Tænia saginata*, or *Tænia mediocanellata* as it is sometimes called, is produced by eating the flesh of the ox and cow, containing cysts called *Cysticerci bovis*, and *Tænia solium* is produced by eating the flesh of the pig, containing cysts called *Cysticerci cellulosæ*. Measles in the ox and pig are due to these *Cysticerci*. In flesh that is affected by them they appear as small rounded or oval bladders of a whitish colour (figs. 22 and 23). The *Cysticercus bovis* (figs. 24 and 25) is small, being about 7 to 9 millimetres long and 5 millimetres broad, while the *Cysticerus cellulosæ* (fig. 26) varies from 5 to 20 millimetres in length, and from 5 to 10 millimetres in breadth.

Inspecting live animals the cysts or bladders are generally most easily detected in the conjunctivæ, and the loose tissue of the frænum of the tongue of the

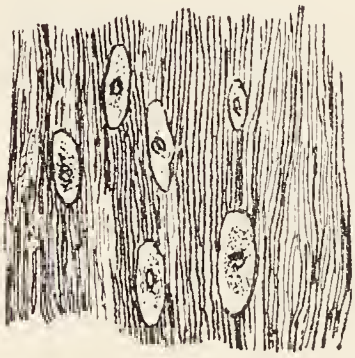


FIG. 22.—Measly beef. Cysticercus of *Tænia saginata* embedded in the muscle (natural size). Leuckart.

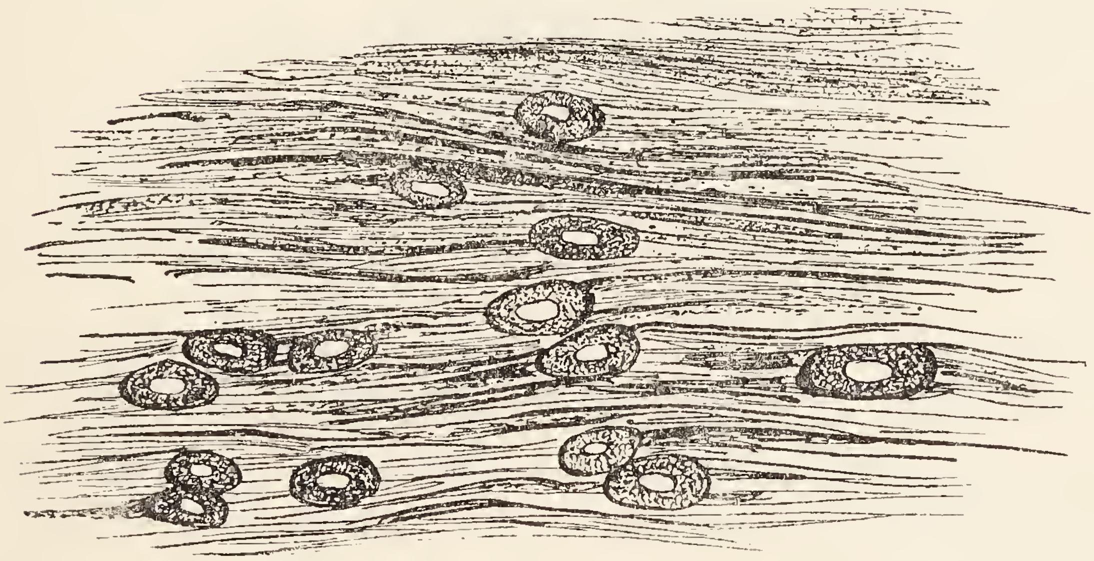


FIG. 23.—Measly pork. Cysticercus of *Tænia solium* embedded in the muscle (natural size). Leuckart.

FIG. 24.—*Cysticercus bovis* with evaginated head (× 3). Leuckart.

pig and in the internal and external pterygoid muscles of the ox. In slaughtered animals the liver, shoulders, intercostals and loins should be specially examined. If

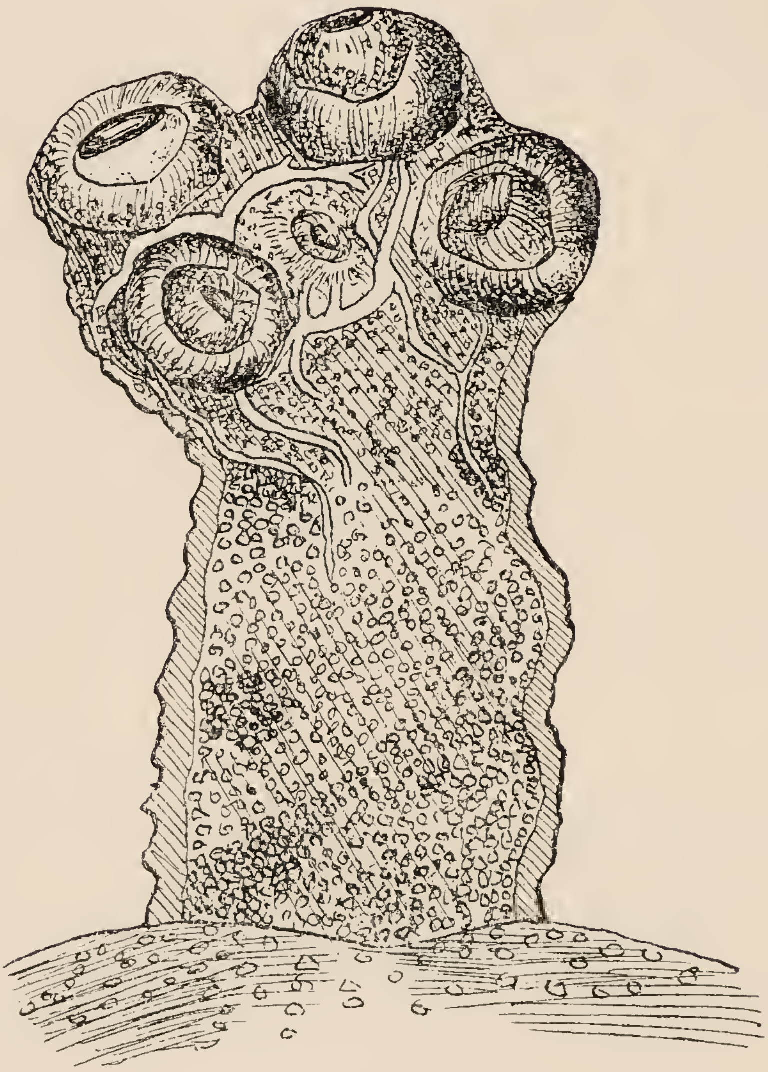


FIG. 25.—Head of cysticercus of *Tænia saginata* (*Cysticercus bovis*), with suckers and vascular ring (× 30).

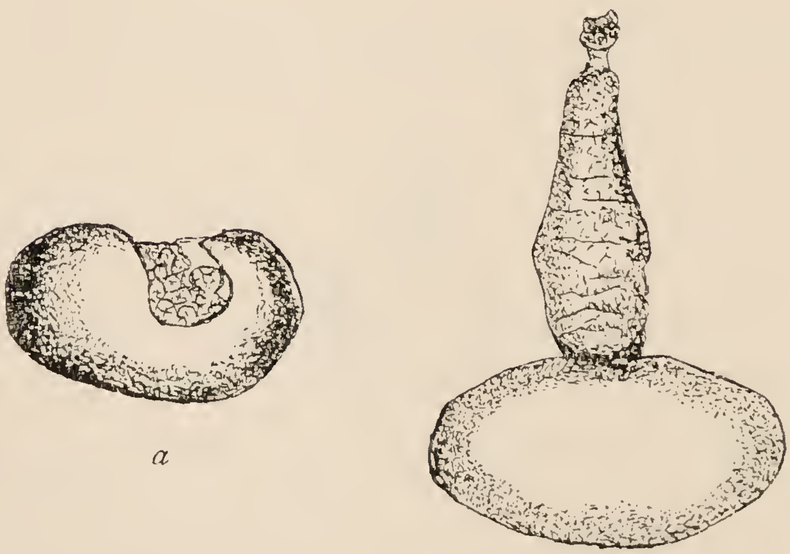


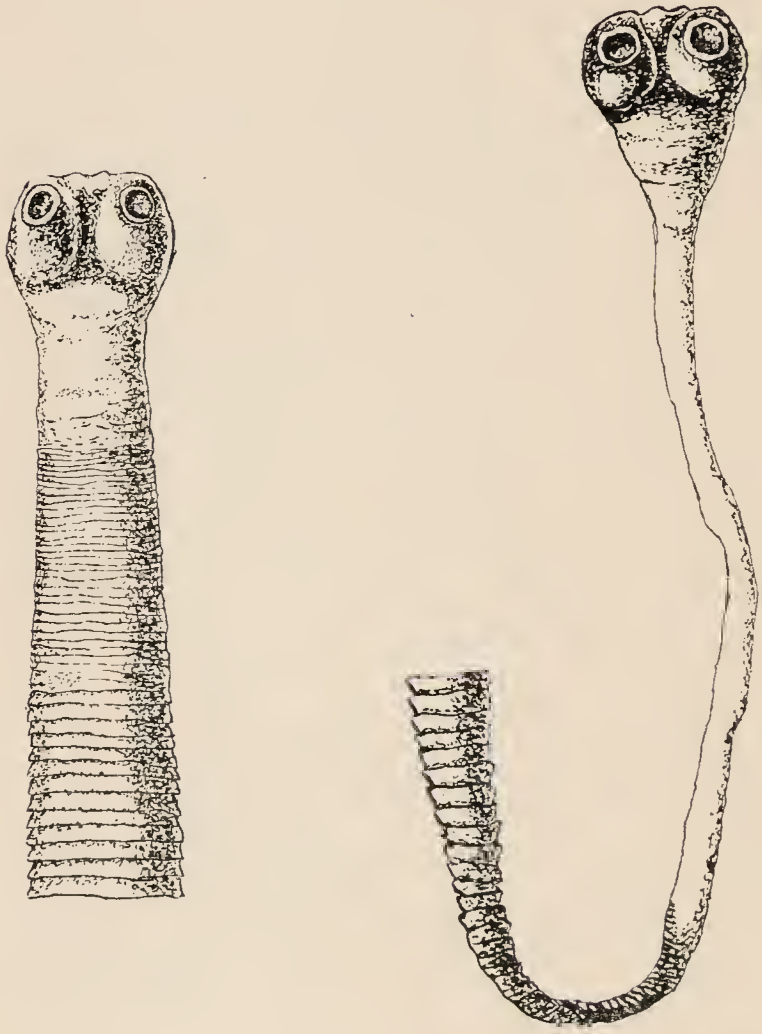
FIG. 26.—*Cysticercus cellulosæ*, the common bladder-worm of the pig. (*a*) With the head in the receptacle (× 2). Leuckart.

the bladders or cysts are cut open and examined by a quarter-inch lens, they will be found to contain the scolex or future head of the tapeworm, from which, when it settles in the intestine, are derived from its posterior extremity the numerous proglottides that make up the parts of the fully developed tapeworm, which arrives at maturity in about twelve weeks. The bladders may be simply pressed, which is often sufficient to protrude the invaginated head, which may be then examined.

The great difference between the scolex of the *Tænia saginata* and of the *Tænia solium* is that the first has suckers, no hooklets and a depression on its head, while the second has suckers and a wreath of hooklets attached to a prominent rostellum.

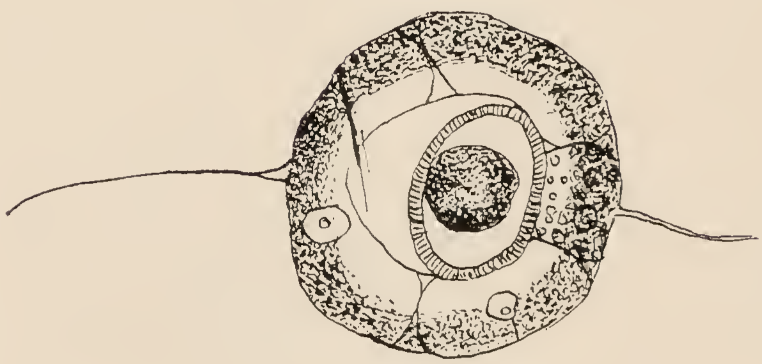
The following particulars as regards the heads of these tapeworms, their proglottides, and ova, may be useful ; other *Tæniæ* besides *saginata* and *solium* are occasionally found in man, but as they are not caused by the meats ordinarily used for food, they need not be mentioned here. The only other *Tænia* of importance is the *Dibothriocephalus latus*, the cysticercus of which reaches man by his eating insufficiently cooked certain fish of the pike and salmon kind.

The head of *Tænia saginata* is cubical in shape, has no hooklets but possesses four suckers, which are frequently surrounded by a pigmented border. The neck is about half the breadth of the head. The proglottides of a mature worm number generally over 1,000, and are each about 16 to 20 millimetres in length and 4 to 7 millimetres in breadth. The worm itself may be 8 metres in length. The first five or six hundred proglottides are not fully developed with germ-producing organs. At each side of the median trunk of the uterus there are many ramifying lateral branches. The eggs are globular and possess a shell which sometimes remains intact when outside the body. Within this yolk shell is the oval and transparent embryonal shell which is radially striated and measures about ·03 to ·04 millimetre in length and ·02 to .03

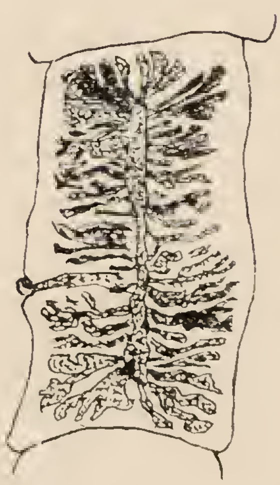


a *b*

Cephalic end of *Tænia saginata* (*a*) in retracted, and (*b*) in extended state (× 8). Leuckart.



Egg of *Tænia saginata*, containing the embryo. Leuckart.

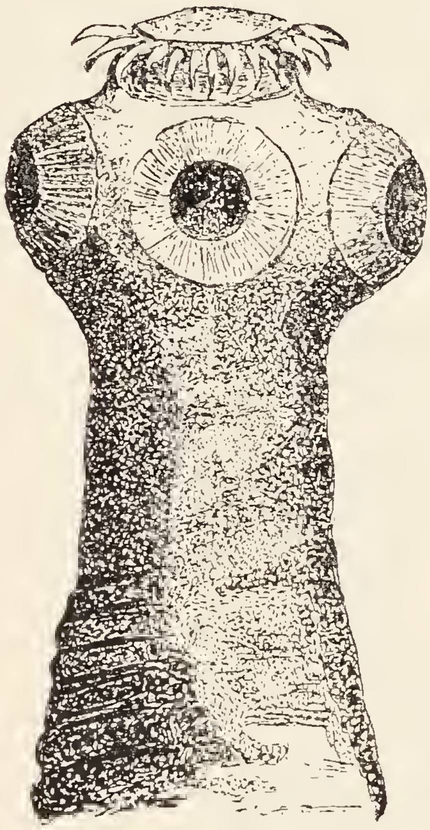


Mature segment of *Tænia saginata*. (× 2). Leuckart.

FIG. 27.

in breadth. Within this again is the oncosphere or embryo with its three pairs of hooklets.

When mature proglottides containing ova are swallowed by the ox, the embryos are set free in the stomach, and



Head of *Tænia solium* (× 45). Leuckart.

Two proglottides of *Tænia solium*, with branched uterus (× 2). Leuckart.

a *b*

Eggs of *Tænia solium* (*a*) with, and (*b*) without primitive vitelline membrane (× 450). Leuckart.

FIG. 28.

by means of their hooklets are believed to reach the portal circulations by which they are carried to the liver and other parts of the body where they lose their hooklets and undergo development into cysts with scolex.

If the ova of tapeworms are sometimes swallowed by man owing to the contamination of vegetables or salads, either directly or by being washed with water which contains them, in this case the embryos reaching the stomach may give rise to cysticerci in man. Similarly the ova may be swallowed with the same result—when man is suffering from tapeworm and through uncleanliness of the hands or insanitary conditions the ova reach the mouth.

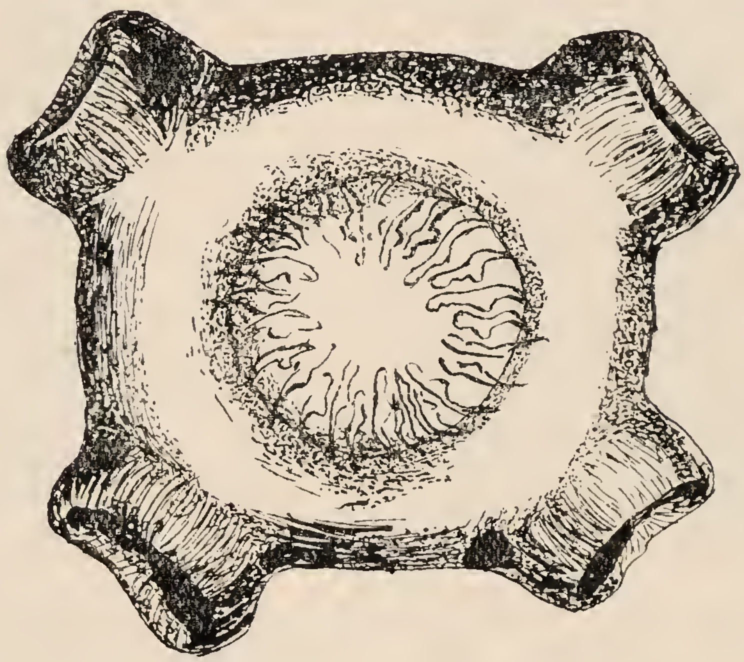


FIG. 29.—Apical surface and circle of hooks of *Tænia solium.*

The head of *Tænia solium* is globular in shape, with a rostellum, sometimes pigmented, bearing a double wreath of alternating large and small hooklets, generally from twenty-six to twenty-eight in number. The suckers are prominent and hemispherical (fig. 29). The proglottides of a fully-developed worm average from 800 to 900 in number, only the last hundred being mature, and these are about 12 millimetres in length by 5 to 6 millimetres in breadth. The full length of the worm is seldom over $3\frac{1}{2}$ metres, being about half the size of *Tænia saginata.* The median uterine trunk gives off only a few lateral ramifying branches. The eggs are oval, the eggshell thin ; within the eggshell is the embryonal shell radially

striated in a similar way to that of *Tænia saginata*, and about the same size, viz., ·03 to ·04 mm. in diameter. Within this embryonal shell is the embryo with its six hooklets.

The oncospheres or embryos when swallowed by the pig undergo a similar distribution and development to those described in regard to the cysticercus of the *Tænia saginata*. The cycle of the cestode parasites thus consists in proglottides containing ova, or free ova, being passed from the intestines of some one suffering from tapeworm; the swallowing of these in food by an ox or pig, the setting free of the embryo in the stomach of the animal, the migration of the embryo, aided by its hooklets, to the liver through the portal blood-vessels, its further distribution to different parts of the body, its selection of the muscular system for its embedment, and its development there into a cyticercus. When the meat containing the cysticercus is swallowed, the scolex gets protruded and attaches itself to the small intestines, the bladder-like portion becomes dissolved, and there is produced from the posterior extremity of the scolex or head a succession of proglottides, until the fully developed tapeworm is formed.

Neither salting nor smoking destroys the scolices inside the bladders, and as it is always doubtful whether the meat will be so thoroughly cooked as to expose the cysticerci to a temperature of 50° C. to 60° C., which kills them, the meat should be destroyed. Pork is not eaten by Hindus, Mahomedans or Jews, hence, in a large part of the Tropics, *Tænia solium* is unlikely to occur. In the Tropics generally the pig is a foul feeder and scavenger, and hence is considered not suitable for food. Its flesh is known at times to have produced intestinal disturbances. The Chinese are very fond of pork, but they generally cook it well.

Wherever animals are slaughtered for human food they should be subjected to careful inspection before and after slaughtering, with the view of determining their fitness for human food.

There are numerous other cysts or hydatids connected with tapeworms of other animals to be found in the organs of animals used as food, but they have not that direct bearing on the health of man which is connected with the presence of *Cysticercus cellulosæ* or *Cysticercus bovis.* Thus may be mentioned the *Echinococcus veterinarius,* which is derived from the *Tænia echinococcus* of the dog, and is often found in the lungs and liver of cattle. The *Cœnurus cerebralis* from the *Tænia cœnurus* of the dog may be found in the brain and spinal canal of the ox and sheep, causing staggers. The *Cysticercus tenuicollis,* from the *Tænia marginata* of the dog, in the abdomen and pelvis of sheep, pigs, oxen and fowls. The organs of infected animals should not be permitted to be used for consumption, but should be boiled in a cauldron in the slaughter house to destroy the hydatids, before being burned or otherwise disposed of.

The affected organs should not be given to dogs, for the hydatids will develop into tapeworms in the intestines, and the ova being passed by the dog may contaminate uncooked vegetables such as salads, and be thus swallowed by man, causing in him the cysticercus stage or echinococcus. The infection of dogs with the *tænia* may also be dangerous to men by the dog transferring the oncospheres to him by licking his hand, or dishes on which food is placed.

Trichina cysts may also be found in pork, and from their minute size may easily be missed. Fortunately trichinæ are only to be found in the flesh of pigs, and as swine flesh is an abomination to the vast majority of the people in the Tropics, these nematodes have not the same sanitary importance as in colder climates. Still, wherever pigs are killed for human consumption (*e.g.,* in China, Fiji, and many other places), examination should always be made for trichinous cysts, which are oval or lemon-shaped, and contain coiled up within them the young form of the nematode worm. The cysts are minute compared with the size of cysticerci, and appear

as small specks on the flesh of an infected animal; they only measure about ·4 millimetre in length, and a little over half that in width. They are usually found more crowded together in the muscular parts of the diaphragm, the muscles of the larynx, tongue, abdomen, and intercostal spaces, and also at the ends of muscles near their attachments.

For examination a thin section of the meat should be taken from one of these favourite seats of the parasite, teased out and pressed between two slides, and carefully examined microscopically with an objective magnifying 25 diameters, *e.g.*, with a 2-inch objective and a No. 2 ocular. Or the thin section of meat can be put in a watch glass containing acetic acid. In a few minutes the tissue becomes transparent. It is then taken out and washed and mounted in water or glycerine, and examined.

As exposure to a temperature of 70° C. for a considerable time is required to kill the trichinæ, any meat that is found trichinous should be condemned, boiled and destroyed. *Trichinæ spiralis* are found in the rat, pig, dog, cat, and other animals which destroy the rat. They do not occur in the flesh of fowls, pigeons or ducks, but experimentally the adults can live in the intestines of these, their young being passed in the fæces. In this way it is possible for them under insanitary conditions to reach the alimentary canal of man without the eating of infected pork.

When a piece of infected pork is eaten, the capsule is dissolved by the gastric juice, and the worms enter the small intestines and rapidly attain maturity, the male being about half the size of the female, which is about 1·5 millimetres long. After impregnation the female grows still longer, bores into the mucous membrane and deposits her young in the lymphatic spaces. The larvæ are carried by means of the lymph stream and circulating blood to different parts of the body. They pierce the capillaries, and then settle in the various striated muscles.

The first brood reaches the muscles in nine or ten days after infection, and other broods may continue to arrive for a period of over a month, during which time the adult worms live in the intestines, and give off their young. Once having located themselves in the muscles the young nematode undergoes capsulation, the parts of the muscle affected losing their striae, and the capsule being formed by inflammatory changes in the connective tissue. Later the capsule may become calcified. Each female trichina gives birth to a brood of a hundred or several hundred young trichinæ.

There are certain trematode worms found in herbivorous animals used for human food, which are to be also found in man. Their presence in the intestines and organs of the lower animals is not considered of much sanitary importance. For they require before undergoing development in man or the lower animals an intermediate cycle of their existence, or even two cycles in such hosts as snails, molluscs, fishes, arthropoda, and other aquatic animals or even on plants. Thus the life history of the digenetic trematodes is that in the bile ducts, organs or intestines of the terminal host the distomum or fluke reaches its full development and matures its ova which are then discharged and leave the body. The miracidium or embryo arriving in water breaks through its shell, becomes free and swims about by means of its cilia. It then penetrates a snail or mollusc becoming a sporocyte with rediæ which form cercariæ or tadpole-like organisms which leave their host and either become encysted in some other host or in water attaching themselves to plants or grass.

The most common mode of acquiring them is by swallowing the encysted stage of the trematode either in an intermediate host or in water, or when attached to grass or plants; water cress and salads may contain the encysted form. Ducks and geese become infected by swallowing certain water snails containing the encysted form. Oxen get infected by swallowing with the water

the encysted forms at the bottom of puddles and ponds. Sheep are infected by eating grass to which the encysted forms are attached.

If Loos is correct in his opinion that the free miracidium of the distomum or *Schistosomum hæmatobium* does not require an intermediate host, but can develop in man by entering the system through the skin when bathing, it may also be possible for it to develop in man after eating infected food.

The *Distomum hepaticum* or liver fluke is the widest in geographical distribution, and is the most common variety to be found in sheep, oxen, buffaloes, goats and other herbivorous animals. It gives rise to a cirrhosis of the liver, which in sheep may give rise to sheep rot, a disease that may be very fatal and sometimes epidemic in its character.

Other species of larger size have been found in Egypt and Senegambia; another species, of small size, the *Distomum westermani* or *Paragonimus westermani*, has been found in pigs, while the distomum or *Schistosomum hæmatobium* has been found in sheep and oxen in Egypt, South Africa and India. The organs and intestines of infected animals suffering from any distoma should be destroyed.

At least the organs and intestines of animals suffering from trematodes should be destroyed, which is best done by boiling and then burial.

Coccidiosis is a disease which occasionally affects rabbits, cattle and sheep. It is caused by psorosperms. Of the best known psorosperms, the *Coccidium oviforme*, is found in the bile ducts or enclosed in their epithelial cells, and occurs in rabbits, while the *Coccidium perforans*, which is small, is found in the glands and epithelial cells of the intestines of rabbits, fowls, and sheep.

Tinned fish like tinned meat, if not properly preserved, may cause poisoning when eaten. The symptoms are those of ptomaine poisoning. There is vomiting and

purging, rapid and feeble pulse, collapse, fever, delirium, restlessness, and great prostration. Fish rapidly loses its freshness in the Tropics and soon decomposes. In fresh fish the gills are bright and red, and are not muddy, pale or discoloured, the flesh is firm, stiff and elastic, and the smell is pleasant. In examining fish it is not to be forgotten that occasionally the gills are coloured with blood to conceal any signs of change. If tainted or decomposed, pressure of the fish between the fingers and the thumb either causes an indent that remains or separates the skin from the flesh, the tail droops when the fish is held horizontally, the skin may be iridescent, the flesh easily separates from the bone leaving a brown mark like that of a rusty nail when withdrawn from a plank, and the smell is characteristically that of decomposition.

Stale and decomposed fish cause acute gastro-intestinal symptoms of a choleraic nature, and when found in market, shop, or elsewhere, on sale, should be seized and destroyed. Dried fish is often mixed with fish that is more or less in a state of putridity; under such circumstances the consignment should be destroyed.

Neither fresh fish nor shell fish is wholesome out of season. Many acquire poisonous properties when spawning while others in tropical seas are never safe owing to feeding on poisonous medusæ and corals. The tunny, which is harmless on the European coasts, causes illness when taken in the West Indies; similarly the horse mackerel at Guadaloupe, the Scorpæna at St. Domingo and the fuga in Japan, are poisonous at certain seasons and at certain parts of the coast. The Indian mackerel and sardine on the Malabar coast are sometimes poisonous and often the Bombay oyster causes serious illness when taken out of season, or when not absolutely fresh.

Prawns sometimes give rise to dysenteric symptoms, and mussels to gastritis and enteritis accompanied sometimes with poisoning due to mytilotoxin, an alkaloid similar to that of curare.

There are fish in the tropical seas that are poisonous at all times; for instance, most of the Tetrodon and Diodon species, the guiet, the false horse mackerel, the Ostracion or trunk fish and the toad fish of the Cape.

The symptoms of poisoning are usually diarrhœa and vomiting, flushed face, dilatation of the pupils, reddening of the tongue, irritation of the throat, pains in the joints, dysuria, irritation and itching of the skin, small and frequent pulse, and syncope.

Fish may also produce true cholera symptoms occasionally. Oysters have also caused cholera in India, and there can be no doubt that they are responsible for cases of typhoid fever in the Tropics though the proofs establishing the fact have not been forthcoming in the same way as in Europe and America. I have found in the intestines of fish comma bacilli similar in every respect to the comma bacilli in man suffering from cholera. There is on record an outbreak of cholera in St. Petersburg in 1893, when 194 out of 200 inmates of an orphan institute were attacked with cholera within a week at the commencement of a fast, and the outbreak was attributed to the consumption of fish taken from a cholera-infected water.

Fish may also contain cysticerci and unless well-cooked produce tæniæ. The best known is *Dibothriocephalus latus.* The appearance of the ovum, embryo, larva, and head of this tænia is showed in fig. 30.

Fresh Vegetables.—There are many dangers attaching to the eating of salads and raw vegetables in the Tropics and particularly so where the gardener is a Chinaman. The ova of certain worms such as anchylostoma, &c., round worm, and the bacillus of enteric fever, cholera, dysentery, and probably of sprue, may be thus taken into the system. Wherever the Chinaman is to be found, and he is distributed over many parts of the Tropics, he carries with him his own methods of raising vegetables; an excellent agriculturist he will grow garden produce where others fail. The danger lies with him in his mode

Free swimming embryo of *Dibothriocephalus latus* (× 600). Leukart.

Eggs of *Dibothriocephalus latus*. Leuckart.

Larvæ of *Dibothriocephalus latus*. Leuckart.

Head of *Dibothriocephalus latus*. Leuckart.

FIG. 30.

of applying the sewage to the plants, together with his disregard of the water he washes them in, while for the most part in other circumstances where he is absent, the

FIG. 31.—Chinaman watering Vegetables with Sewage.

chief danger is from the kind of water the vegetables are washed with. Fig. 31 shows a Chinese gardener sprinkling the vegetables with night soil and urine.

CHAPTER VIII.

EXAMINATION OF MILK AND GHEE.

THE purity of milk, ghee or melted butter, and mustard oil, is important in the Tropics because these articles, especially in India, enter largely into the dietary of the people. For this reason the following short description is given of the procedures necessary in order to determine their purity.

Detection of Adulteration in Milk.—In dealing with adulteration of milk it is necessary to know what variations of the constituents occur in normal milk. That milks from different cows differ in the percentage of their total solids, and of their milk fat is well known, that these percentages differ even in the same animals in different seasons is also established. But it is equally well established that these percentages do not, unless under very exceptional circumstances, go below a certain limit which can readily be fixed if a sufficient number of analyses be made with that object during the different seasons of the year. The analysis consists in ascertaining the specific gravity of the milk, the total solids it contains and the amount of milk fat.

In 1901 a Committee of the Board of Agriculture recommended for England that any sample of milk which contained less than 12 per cent. of total solids, less than 3·25 per cent. of milk fat, and less than 8·5 per cent. of non-fatty solids should be deemed to be so deficient in normal constituents as to raise a presumption until the contrary is proved that the milk has been tampered with.

The Board of Agriculture, by its regulation of August 5, 1901, fixed the minimal limits as 3 per cent. of milk fat, and 8·5 per cent. of non-fatty solids.

This limit was adopted in Calcutta as far back as 1894, based on a series of experiments made in 1889, extending over the rainy season and cold weather, on eighteen Bengali cows, which were fed in native fashion under supervision, supplemented by similar investigations carried out at a later date but on a much larger and more extensive scale by Dr. J. Dutta and Dr. S. B. Ghose, of the Calcutta Municipality. Mr. Cripper, F.C.S., also made a series of analyses of milk at the earlier period.

The general results of these investigations were for cow's milk :—

BENGALI COWS

Constituents	Stevenson and Simpson		Cripper	Dutta and Ghose		
	Rainy season	Cold weather		Minimum	Maximum	Average
Specific gravity ...	1028	1032·6	1028 to 1030	—	—	—
Total solids ...	12·93	14·67	13·8	11·9	14·8	12·84
Non-fatty solids ...	8·55	9·87	8·9	8·9	9·98	9·1
Fat	4·38	4·80	4·88	3·14	4·9	3·34
Casein, albumin, &c.	3·33	4·01	3·84	4·32	4·5	4·4
Sugar	4·54	5·11	4·4	4·3	4·8	4·4
Ash	·68	·75	0·7	·7	·79	·75
Water	87·07	85·33	86·18	85·2	88·1	86·23
Total ...	100	100	100			

For buffalo's milk :—

	Simpson and Stevenson : Milk of buffalo in cold season	Cripper	Dutta and Ghose		
			Minimum	Maximum	Average
Specific gravity at 60° F....	1033·30	—	1031	1035	—
Total solids	18·88	17·38	16·36	19·5	18·7
Non-fatty solids	10·86	9·9	10·46	11·5	10·75
Fat...	8·02	7·5	7·0	9·5	8·57
Casein, albumin, &c. ...	4·72	4·11	4·4	4·96	4·66
Sugar	5·38	4·95	4·8	5·6	4·86
Ash...	·76	0·8	·7	·8	·746
Water	81·12	82·6	80·5	83·64	81·5
Total ...	100·00				

From the data thus obtained the following standards were adopted:—

Constituents	Milk: Cow	Milk: Buffalo
Water	88·5	83·5
Total solids	11·5	16·5
Non-fatty solids ...	8·5	10·5
Fat	3·0	6·7
Ash	0·7	0·7

Any cow's milk containing less than 11·5 total solids, 8·5 non-fatty solids, and 3·0 milk fat, was considered not to be genuine milk and the vendor was prosecuted.

These analyses, under the special conditions mentioned, established the fact that the composition of cow's milk in Calcutta is the same as that in England, and that buffalo's milk is twice as rich in fat, and contains a larger amount of total solids than cow's milk.

In 1899 and 1900, Mr. Walter Leather, Ph.D., F.I.C., made a number of analyses of the milk of Indian cows and buffaloes in the Bombay and Madras Presidencies. The chief difference from the Calcutta analyses is the uniformly high specific gravity. This is probably due to the fact that Mr. Leather's analyses were all made in the cold, and beginning of the hot season, and not during the rains, when, as has been shown, the milk is poorer.

The composition of milk from cows in a tropical region is similar to that in a temperate climate, and the adulterations are also similar. Water added to milk is the most common adulterant all over the world. The extent ranges from 20 to 60 per cent. in India. In Bengal it is a recognized custom to add one part of water to every three parts of milk. Were it not for the fact that the natives of India always boil their milk, a large amount of disease would be caused by this wholesale adulteration which is generally with water from wells, tanks and ponds, contaminated often with sewage.

Many cases of typhoid and cholera in Europeans who sometimes omit the precaution to boil the milk they drink are traceable to adulterated milk. The next most common adulterant is batassa or molasses, used to raise the specific gravity when this is lowered by the addition of water. Next comes the removal of cream. Occasionally the addition of arrowroot and portions of banana, or plantain is made. The preservatives so commonly used in European countries are not used ; boric acid, salicylic acid and formaldehyde being, as a rule, beyond the reach of the milk-seller in the Tropics.

The methods for the detection of adulterants may be divided into two classes. The first are useful when on inspection at the marts or elsewhere. The second are the ordinary laboratory methods.

Rough methods.—For the detection of added water the lactometer should be employed. Any milk lower in specific gravity than 1·028 is presumptively adulterated with water. This can often be readily confirmed by the following test for nitrites ; coagulate some of the milk in a test tube with a little acetic acid, filter it and add to the filtrate a few cc. of an equal mixture of sulphanilic acid and naphthylamine sulphate, when, if nitrites are present, a rose-red colour will be produced. As most of the milks are adulterated with contaminated waters which contain nitrites this is a useful test.

For the detection of cane sugar in the form of molasses or batassa, there is Cotton's test or the resorcin test.

Cotton's Test.—This test can be generally more usefully and more conveniently applied in the laboratory. Two tubes are required. Into one containing 10 cc. of the suspected milk are put 5 grams of ammonium molydate and 10 cc. of dilute hydrochloric acid of the strength of 1 in 10. In a second tube a 6 per cent. solution of lactose is treated in the same way. Both tubes are put in a water bath, and the temperature gradually raised, when it will be noticed that at about 80° C. if

the milk contains cane sugar it will assume a blue colour, while the lactose solution will remain unaltered. If raised to the boiling point the lactose solution will become slightly blue, but never becomes the intense blue of the milk which contains molasses. The test will detect ·1 per cent. of cane sugar.

Resorcin Test.—Add to 10 cc. of the milk about 0·1 gram of resorcin, and a few drops of hydrochloric acid and boil for a few minutes. If cane sugar is present a rose-red colour is produced.

Examination of Milk in the Laboratory.—It is only in a few places in the Tropics that there is a well equipped laboratory. But much valuable information as to the presence of starches, the specific gravity of the milk, the percentage of milk fat, and the percentage of solids not fat, can be obtained by the employment of the microscope, the lactometer, a centrifugal machine, and Richmond's milk slide scale. The microscope will detect the presence of starches or other foreign matter, such as dirt, pus cells, &c. If starches are suspected the further test of adding a small quantity of a solution of iodine in potassium iodide to the whey can be made. If starch is present a blue colour is produced.

The lactometer will give the specific gravity of the milk. The best lactometers are the Thermo lactometers, and Soxhlets ordinary lactometers. The former has the advantage of indicating the temperature of the milk at the same time that the specific gravity is taken. With the latter the temperature of the milk has to be taken immediately after the specific gravity has been recorded. When the lactometer has been placed in the milk and becomes stationary, that degree of the scale which is on a level with the surface of the milk indicates the specific gravity. If after correction for temperature the specific gravity is below 1·028 or above 1·033, the milk is likely to have been tampered with. Milk below a specific gravity of 1·028 contains either an exceptional amount of cream or is adulterated.

The Leffman-Beam Process.—The Leffman-Beam Centrifugalizer is generally employed in the Leffman-Beam method of ascertaining the amount of milk fat as the test flasks easily fit into it. The Leffman-Beam process allows of a very rapid and easy analysis as regards the amount of fat in milk, and is sufficiently accurate when compared with the results obtained by the gravimetric method as to render it quite reliable. The difference is rarely more than ·1 per cent.

For the Leffman-Beam process specially constructed test flasks are used which will contain 29 cc. of fluid. These test flasks have a long neck which is carefully graduated to 80 divisions, equalling a capacity of 1·475 cc.

The tube which makes up the neck of the flask has an internal diameter of 5·96 millimetres. Into this flask is measured 15 cc. of milk by a pipette, the point of which is held against the side of the neck, then 3 cc. of a mixture containing equal parts of amyl alcohol, and hydrochloric acid is added, 9 cc. of strong sulphuric acid is next carefully poured in, and the flask gently rotated to mix the contents. The flask is then filled up to the zero mark in the neck, with a hot mixture of one part of strong sulphuric acid to two parts of water. The flask is then placed uncorked in the centrifugal machine, and centrifugalized for two minutes. By this time the fat has risen to the surface as a clear liquid, and as each division of the graduated neck represents $\frac{1}{10}$ per cent. the number of divisions occupied by the clear fat represents the amount of fat in the milk. Thus if the fat occupies 35 divisions, the percentage of fat in the sample is 3·5 per cent. The reading should be done immediately after taking from the centrifugalizer. Should a little of the fatty layer be below the lowest graduated part of the neck a little more of the 1 in 3 hot sulphuric acid should be added, and the contents of the flask again centrifugalized. This will bring the fat up to the level where its amount can be read off.

Any milk containing less than 3 per cent. of fat is usually adulterated.

Richmond's Slide Rule or Milk Scale to determine the total Solids.—The specific gravity having been ascertained by the lactometer and the percentage of milk fat by the Leffman-Beam process, the amount of total solids can be readily found by using Richmond's milk slide rule. This slide rule has three scales, two of which—the fat and total solids—are marked on the rule, while the specific gravity is on the sliding scale. The arrow on the scale is adjusted so as to point to the figure on the rule representing the percentage of fat as found by the Leffman-Beam process, and the figure on the scale for the specific gravity determined will then be opposite to the figure representing the percentage of total solids. The difference between this last figure and that of the milk fat gives the percentage of solids not fat in the milk.

The amount of water added is calculated from the solids not fat by the formula.

$$\text{Water} = 100 - \frac{S}{8{\cdot}5} \times 100$$

where S = solids not fat.

Analysis of Milk in the Laboratory.—The ordinary laboratory tests are employed and need not be described with fullness. Briefly, the total solids, milk fat, and specific gravity are taken, and usually the gravimetric process is employed.

The total solids are determined by drying 5 grams of milk in a dish on the water bath, and then in the water oven until the weight becomes nearly constant, which is taken to be the case when the loss is less than a milligram per hour. The fat may be estimated by one of the following methods, viz., by dry extraction, by wet extraction, or by centrifugalizing the milk. There are two dry extraction methods, the Wanklyn method and Dr. Adam's paper coil process. In the Wanklyn method the dried residue of 5 grams of milk has its fat extracted by washing three or more successive times with

ether. The fat thus extracted is weighed after the ether is evaporated. The weight of fat deducted from that of the total solids gives the amount of non-fatty solids. Dr. Adam's method consists in the use of a coil of blotting paper to absorb a definitely weighed quantity of milk. The coil is then dried in an oven for two hours, and the fat is extracted by ether in a Soxhlet apparatus.

The Werner-Schmidt method is a wet extraction process. It consists in measuring 10 cc. of the milk into a graduated 50 cc. tube and adding 10 cc. of strong hydrochloric acid, and heating until the mixture is brown. The mixture being cooled by immersing the tube in water, 30 cc. of ether are added, a cork inserted, the contents thoroughly shaken up, and the fat extracted. The tube is set aside to allow the etherial solution to separate the volume of which is noted, and from which 10 cc. are taken and evaporated in a weighed platinum dish, from the result of which the fat may be estimated.

The specific gravity of milk is determined either by a lactometer, a specific gravity bottle, a Sprengel tube, or a Westphal balance. Of these the most commonly employed is the lactometer. The specific gravity of milk in the Tropics varies from 1028 to 1033. In normal milk the specific gravity is less in proportion as the fat is greater.

The bacteriological examination of milk is usually employed to detect the bacillus of tuberculosis and that of cholera. The only reliable test for the bacillus of tuberculosis is its pathogenic action on susceptible animals. A small quantity of the milk is centrifugalized and 2 cc. of the milk containing the deposit are inoculated into two guinea-pigs. If the milk contains tubercle bacilli the animals will show it in from three to six weeks time. A quicker method is to inject the suspected cows with tuberculin when a strong reaction indicates the presence of tuberculosis, but this of course is impractical unless the source of the milk be known.

In the case of cholera, isolation of the microbe can be

effected by inoculating Dunham's peptone solution with 1 cc. of the milk, and then plating the growth on agar or obtaining isolated colonies by inoculating successively half a dozen or more sloped tubes of agar, without charging the inoculating needle more than once. The isolated colonies in the sixth or last tube can then be examined for cholera bacilli.

Ghee.—There are two kinds of ghee, that which is prepared from the milk of the cow, and that which is prepared from the milk of the buffalo.

Buffalo ghee is whiter in appearance, it contains more soluble volatile acids as determined by the Reichert Wolling process, corresponding generally to from 34 to 39 cc. of deci-normal alkali for 5 grams of ghee. In forty samples of purified ghee carefully prepared from pure buffalo milk in the Calcutta Municipal laboratory for standardsation purposes, the minimum Reichert value, in terms of deci-normal soda, was found by Dr. J. Dutta and Dr. S. B. Ghose to be 30·5, and the maximum 39·3, the average being 34·5 for 5 grams of the ghee, while the minimum Reichert value for ghee from pure cow's milk was 22, the maximum 27, and the average 24, for 5 grams. Cow's ghee possesses a very pleasant sweet smell.

Preparation.—Two methods are employed in preparing ghee. The most common method is to curdle the milk with dobi, which is sour milk, and to churn until the butter is separated, a little water being added so that the butter floats to the top. The butter is collected, washed thoroughly in water, and is then placed in an iron pan which is placed over the fire. The butter melts, the casein and water fall to the bottom, and the heat is raised so as to evaporate the water and the casein is slightly charred. This is called *pucka* or valo ghee, as distinguished from *kutcha* in which the water is not evaporated and the ghee is not charred, the ghee being simply collected by decantation. The *pucka* ghee is considered to be the best, and is used principally to

mix with rice and other articles of food when ghee is taken with food as such, and not merely used in the preparation of the food.

The *kutcha* ghee is used by the sweetmeat makers for frying purposes, and for preparing food stuffs. If *kutcha* ghee is bought and is required for mixing with food stuffs at meal times, it is first of all heated in an iron pan to convert it into valo or good ghee.

The second method of preparing ghee is to churn the colo milk into butter without first making it sour. This is the process chiefly employed by the gowalters or milkmen who churn their milk, take out a portion of the butter or cream thus formed, which they use for ghee, and the rest they sell as milk. Buffalo milk being very rich in fat is generally treated this way.

The uses to which ghee is put are many. First, it is used in preparing food stuffs such as different kinds of sweetmeats, fried bread (luchi), and bread over which ghee is spread (ruti); secondly, for dietetic purposes, such as adding ghee to cooked rice, to curries and to dal's; thirdly, for ceremonial purposes in temples; for religious rites and for cremation. Cow's ghee is the only kind used by the Hindus for their sacrificial and ceremonial rites. Ghee is preserved in earthernware jars, in leathern and in tin cases.

The chief adulterants of ghee are: (1) ground nut oil, called China badam (from *Arachis hypogea*); or (2) animal fats; (3) mowa oil. Ground nut oil has a peculiar smell. Mowa oil has a portion solid and a portion liquid at the ordinary temperature of the Tropics. There are other adulterants used occasionally, such as the oils of cocoanut, poppy seed, sesamum and castor oil. The ghee is not infrequently adulterated by the confectioners in the preparation of their sweetmeats, and to this practice is ascribed much of the dyspepsia among those who have to buy their sweetmeats.

After the careful investigations made by Drs. Dutta and Ghose, the standard adopted for ghee was as follows :—

GHEE.

	Cow	Buffalo
Specific gravity	911—912	911—913
Soluble volatile acids in terms of deci-normal soda by Reichert Wollney method...	24 cc.	30·5 cc.
Melting point	34°—35·5° C.	34—36 C.
Oleo-refractometer at 45° C. ...	−32—35	−32—35
Butyro-refractometer at 40·5° C. ...	41—42·5	41—42·5

Methods of Detection of Adulteration.—Zeiss's butyro-refractometer is largely used in the first step in assorting the samples for analyses. Those that do not conform to the test are set aside for further examination. To prepare the sample for the butyro-refractometer it is melted over a water-bath and filtered. The ghee is then tested. The testing is effected with the ghee in the butyro-refractometer at a temperature of 40·5° C. At this temperature the readings for pure ghee are from 41° to 42·5°. Any sample giving a reading of 43° is regarded with suspicion, and any above 44° as adulterated. Mohua oil from the market shows a reading of 50°; lard, 48·5° to 49°; cocoanut oil, 35°; castor oil, 68°; and ground nut oil, 51°.

To make a reading the prisms of the refractometer are opened, and a drop of filtered ghee is placed on the lower prism. The prisms are then closed, and a reading taken when the temperature is at 40·5°.

Experiments carried on by Dr. Dutta in Calcutta show that pure ghee adulterated with 20 per cent. of ground nut oil gave a reading of 43·5°, while adulteration with 10 per cent. of the oil gave 43°. No difference is observed in the reading between cow's ghee and buffalo's ghee.

Suspected samples are examined further if there is a laboratory, first by the Amagat and Jean oleo-refractometer, which when set at zero with the standard oil supplied with the instrument, gives a reading to the right or

left, according to the kind of filtered oil or fat placed in its hollow or inner prism. Vegetable oils and fats rotate to the right, animal fats and oils to the left. (Cocoa-nut oil rotates to the left some 59°.) Ghee gives a reading of $-30°$ to $-35°$. The temperature of the ghee in the refractometer should be maintained at 45° C., and in melting it the temperature should not be raised above 30° C. All the animal fats have a much lower reading, the nearest approach being mutton fat with $-20°$. The vegetable oils have + readings.

The next method of examination is by the Reichert-Wollny process, to estimate the amount of soluble volatile acids. The Reichert-Wollny number for pure cow ghee is 24° as a minimum, while for pure buffalo ghee the minimum is 30·5°, the average being 34·5°, the maximum being 39·5°.

Butter fat differs from other fats in containing a much larger quantity of volatile fatty acids, soluble in water. Consequently, any marked diminution of the percentage of volatile fatty acids in a butter indicates mixture with other fats. The soluble fatty acids should not be less than 5 per cent. of the fat, and the insoluble should not exceed 89·5 per cent.

Volatile Fatty Acids.—The determination of the volatile fatty acids is effected by the Reichert-Wollny method,[1] which is best carried out as recommended by the Committee of the Society of Public Analysts. The sample of butter is melted, and filtered from curd and water through a dry filter. From the filtrate 5 grams are weighed and introduced into a 300 cc. flask; 2 cc. of a 50 per cent. solution of caustic soda, and 10 cc. of 92 per cent. alcohol are added, and the mixture is heated under a Soxhlet spherical condenser, connected with the flask by a **T** piece, for fifteen minutes in a bath containing boiling water. The saponification being thus completed, the alcohol is driven off by heating the flask on the

[1] *The Analyst*, vol. xxv., 1900, p. 310.

water-bath for about half an hour, or until the soap is dry. The residue is dissolved in 100 cc. of hot distilled water (for this purpose shake the flask frequently), one or two small pieces of pumice stone are added to the solution to prevent bumping, and 40 cc. of normal sulphuric acid. The mixture is then distilled with a Liebig condenser, which should contain a column of water 30 to 35 cm. in length, and the distillation is carried on at such a rate that 110 cc. pass over in twenty-eight to thirty-two minutes. The distillate is shaken, and 100 cc. are filtered off into a beaker, 0·5 cc. of phenolphthalein solution is added, the composition of which is 1 gram in 100 cc. alcohol, and the filtrate is titrated with decinormal soda solution. The result multiplied by 1·1 is the Reichert-Wollny number.

The specific gravity is always taken at 100° F. or 37·8° C., this being the temperature at which there is the largest difference between butter fat and other animal fats. The specific gravity is determined by using a Westphal balance, first of all taking the density of water at 37·8° C., and then dividing the density at 37·8° C. of the ghee by the density of water at the same temperature.

Melting Point.—Ghee is melted over a water bath at a temperature of 60° C. and filtered. A capillary glass tube is then dipped into the ghee, and when about three quarters filled is laid on ice to congeal the ghee inside the tube. It is then attached close to the bulb of a thermometer by an india rubber ring, and both thermometer and tube are immersed in water contained in a beaker with a little ice in it. This beaker is placed in another with water, thus forming a jacket to the first. The whole is put on to a tripod and heated slowly until the congealed ghee begins to melt and rise. The temperature is then noted and recorded as the melting point of the ghee. The melting point of pure cow ghee is from 34° C. to 35·5° C. and buffalo ghee 34° C. to 36° C.

Wellman's colour test for vegetable oil is also useful.

One gram of melted ghee is dissolved in 5 cc. of chloroform, to which are added 2 cc. of phospho-molybdic acid or of sodium phospho-molybdate, and a few drops of nitric acid. The mixture is stirred and agitated. After standing for some time there is a green colouration in the upper layer if vegetable oils are present, but no coloration with ghee alone. If the ghee is rancid the test is not reliable, but if the free acids be separated with alcohol, and the Wellman's test is then applied, the reaction will be given if any vegetable oil is present.

Detection of the Ordinary Preservatives in Foods.

Qualitative Tests for Preservatives. Boric Acid and Borates.—After adding some lime water, the substance is evaporated and then ignited. The ash is then dissolved in water, acidified with hydrochloric acid and a piece of turmeric paper immersed in the solution. On drying the turmeric paper, it is found to be turned pink if boric acid is present. The pink colour is changed to bluish green on addition of caustic soda.

Or the ash may be decomposed with a little pure sulphuric acid, some alcohol added, and on warming and lighting the alcohol, the characteristic green flame will be seen if boric acid or boratus have been added.

Formaldehyde in Milk.—Dilute about 5 cc. of milk with an equal volume of water and gently pour into the mixture strong sulphuric acid so that the diluted milk floats on the top of the acid. A bluish violet ring appears at the junction of the liquids. If the milk contains no formaldehyde the ring is greenish.

If the sulphuric acid is perfectly pure this test sometimes fails, as the presence of an oxidizing agent appears to be necessary. It is therefore advisable to add one or *two drops of perchloride of iron to a very pure acid.* Other foods are examined by distilling some of the aqueous solution or extract and examining the distillate

with Schiff's reagent (an aqueous solution of fuchsine decolourized with sulphurous acid), a red colour appears if formaldehyde is present.

Sodium Carbonate or Bicarbonate.—Add a few drops of a solution of rosolic acid in alcohol. If these substances are present a rose colour appears.

Salicylic Acid.—Acidify the aqueous solution or extract with hydrochloric acid, and extract with ether. The ethereal solution on evaporation leaves a residue which is coloured violet by a dilute solution of ferric chloride.

CHAPTER IX.

CONSERVANCY OR COLLECTION. REMOVAL AND DISPOSAL OF WASTE MATTERS. DRY SYSTEM COLLECTION AND LATRINES.

Waste products undergo a more rapid decomposition in warm than in temperate climates, which necessitates their removal from dwellings as early as possible. If the climate is dry, both the removal and the disposal present few difficulties, but it is otherwise in damp climates and in the region of tropical rains. Then the procedure becomes much more complicated. The rainfall is not distributed equally over the year in moderate showers, but is confined to one or two rainy seasons in the year, and the showers are very heavy. Even in those regions on or near the Equator where the rainfall is more frequent, the showers, though they may be short in duration, are very heavy while they last. The result is sudden flooding, protection against which is not easy.

As elsewhere, the waste products to be removed chiefly consist of domestic refuse, human excreta, solid and liquid, slop water, and the solid and liquid waste of animals kept for domestic and trade purposes.

The most important of the waste products to be dealt with are the excreta and the sewage; the method of removal depending on the existence or not of sewers.

As a rule there are no sewers in villages and in small towns, and in these the waste products have to be removed either by manual labour or cartage. In places in which there are sewers the water carriage system prevails, and foul water and human excreta, solid and

liquid, are removed by the sewers; or the water carriage system and the dry system may be employed separately, the foul water and urine passing direct into the sewers, while the excreta, solid and liquid, may be removed by cartage.

Removal of Excreta, Solid and Liquid, by Manual Labour.

Amount of Excreta to be Removed.—Where no sewers exist, which is the case in the majority of places in the Tropics, arrangements require to be made to collect, remove, and dispose of the excreta, solid and liquid, in as efficient a manner as possible. The first important point in connection therewith is to be in a position to be able to estimate approximately the amount of excreta, solid and liquid, which will be produced daily in a given population. The same estimates which are employed in cold climates, where the inhabitants are meat-eaters, do not apply to tropical climates, where the population are mostly vegetable-eaters.

Vegetable-feeders eat a greater quantity of food than meat-eaters, and their fæces bear a relation to the amount of food taken. There is no difference in the quantity of urine. But as in the Tropics, India especially, water instead of paper is used for cleansing purposes after the bowels are emptied, this ablution water adds to the quantity to be disposed of. Roughly, the excreta, both solid and liquid, of vegetable-eaters in the Tropics is one and a half times to twice that of meat-eaters, *i.e.*, a good average would be 8 oz. solids and 80 oz. liquids, including ablution water. If there is no ablution water the liquids would be reduced to 40 oz.

The quantity to be dealt with in a given population is obtained by multiplying the 8 oz. solids and 80 oz. liquids by the number of people. For example, for 1,000 inhabitants, 500 pounds of solids and 500 gallons of liquid would have to be removed daily; every gallon of liquid

weighs 10 pounds. If ablution water was not used then there would be 250 gallons of liquid, or the amounts may be more conveniently worked out in cubic feet, because most of the pails and carts are made having in view this measure. For this purpose it has to be borne in mind that 1,000 oz. of solids equal 1 cubic foot, and 6·25 gallons of liquids equal 1 cubic foot.

In volume the solid excreta bears to the liquid a relationship of about 1 to 4 or 5, where there is no ablution water, and 1 to 8 or 10 when there is ablution water. As the solids bear only a small proportion to the liquids when there is ablution water, the amount of the liquids to be removed is usually taken and the solids disregarded in the calculation. This, however, cannot be done when no ablution water is used, or when in either case solids and liquids are separately removed.

These estimates for a mixed population with women and children are probably somewhat high, but it is better to estimate for maximums than minimums. Without ablution water it may be roughly taken that each person in the population will give from 14 to 15 cubic feet of solid and liquid excreta in the year, and that amount has to be removed. If there is ablution water it will be raised to 25 or 30 cubic feet.

These are important figures in estimating the amount of land that may be required for the disposal of the excreta, solid and liquid, as well as the number of carts that may be required for removal.

In estimating for a population it is safer at first to take the higher figures. Any over estimate can easily be rectified, but such is not the case with an under estimate. It is from inattention to details of this kind and other causes which will be mentioned later, that the dry method of conservancy so frequently fails in the object for which it is employed, and that in villages and small towns where it is in practice, scarcely more than half the quantity of excreta is removed, and the whole place is in a state of chronic saturation with putrescent filth.

Calculation of Number of Buckets and Carts required for Removal of Excreta.—From the foregoing figures the number of buckets or carts required for the removal of the solid and liquid excreta may be calculated. Buckets and carts are usually made of a standard capacity, each bucket holding 1 cubic foot and each cart 12 cubic feet. Taking then the figures given above for a population of 1,000 persons, there would be of liquids 80 cubic feet, *i.e.*, 500 gallons, divided by 6.25 = 80 cubic feet, or in the case when there is no ablution water and there are only 250 gallons, then 40 cubic feet. The first quantity would require 80 buckets, and the second quantity 40 buckets, if only one trip were made to the trenching ground. But as the mehter or scavenger usually carries two buckets at a time, attached to each end of a bamboo pole, slung over his shoulders, the number of buckets would be reduced by half, *i.e.*, to 40 and 20 respectively, and as it is generally the practice for two trips at least to be made to the trenching ground the number of buckets required would be still further reduced to 20 and 10 respectively. This calculation only refers to buckets of the size used for removal. In the case of pails being used for each latrine they are of smaller capacity and they should be at least in duplicate, that is, one in use at the latrine and one being cleaned. It is often found more convenient to have triplicate sets of pails so that there are always clean pails in storage. The calculation can be made in another way: 15 cubic feet represents the amount of solid and liquid excreta supplied per person per annum without ablution water. This represents ·04 cubic feet per person daily, or 40 cubic feet per 1,000 persons daily. Similarly, if carts were employed to remove the excreta and ablution water instead of buckets, 7 carts would be required if only one trip were made, and 4 in the event of two trips being arranged for, and half this number if there were no ablution water.

These calculations are made on the assumption that in the collection or removal of the excreta the solids and

liquids are mixed. For trenching purposes, however, and especially if the trenching grounds are a long way off, so that the contents of the carts gets churned up a good deal on the way, so as to produce a viscid or colloid condition of the excreta, it is better that the solids and liquids should be collected and removed separately. In that case a due estimate, based on the figures already given, should be made separately for buckets and carts.

Protection of the excreta from rain and flood water essential.—The secret of success in any conservancy system in the Tropics is the protection from rain and floodings. If rain and flood water be carefully excluded from the latrines the amount of excreta, solid and liquid, is always within manageable quantities, and if it has to be carried from the latrine to a place for its disposal there is no difficulty in calculating how much is to be removed, and the service that is required for that purpose. But if rain or flood water is admitted then it becomes an impossibility to efficiently remove the sewage and the whole becomes a fermenting mass of putrefaction, creating a most offensive nuisance which no amount of labour can effectually remove. The great first principle, therefore, in providing latrines, of whatever kind they may be, is to exclude rain and flood water. If this is done conservancy becomes just as easy a matter in the Tropics as it is in the best conducted places in Europe. Without giving practical shape to this principle the best latrine system will rapidly be on a par with the worst. This principle has never been sufficiently grasped, and it is due to the failure to protect against the rain and flood water, combined with the want of calculation of the daily amount of excreta which a population is constantly supplying, that even the best latrines have in the Tropics failed and have presented in a short time no improvement on the most primitive kind.

Whether the latrine is public or private, distant from dwellings or on the premises of a private house, the same principle of protection from rain and flood water

must be borne in mind. The kind of latrine then becomes a matter of contrivance for the engineer or the medical officer.

The latrine, whether of the simplest kind such as the trench, or of the more elaborate kind, should always be protected from rain and flood water. This is done by raising the ground on which the latrine is to be placed, making the surface of the ground slope away from the latrine and providing a roof which will protect it effectively in every part against the rain.

Latrines.—In any system of latrines in which the contents are removed by manual labour, it is better if possible to keep the solids and liquids separate. The latrines will thus be less offensive than when the urine and fæces are mixed. Decomposition sets in very rapidly in the mixture, giving rise to the liberation of ammonia, fœtid organic gases, carburetted hydrogen, &c.

Both fæces and urine in health possess a slightly acid reaction when passed which they retain for some time if they are not mixed. Decomposition is delayed under these circumstances, but sets in quickly when the one is added to the other. Urine when passed into water decomposes less rapidly than when standing by itself, and this fact is made use of in urinals and latrines to keep them free of offensive smells. Lime does not retard but rather hastens the decomposition of urine and should be avoided. In India and the East generally the natives squat to empty the bowels, so that where latrines are provided the seats have to be specially constructed.

Primitive form of Latrines.—For natives in villages where plenty of space is available and where much prejudice exists against using properly constructed latrines the simplest and most effective mode of conservancy is to set apart a piece of ground well removed from the village, have compartments screened off for the men, and for the women and children, have dug in these shallow trenches and insist on the villagers using them. A small quantity of earth requires to be thrown on the excreta

daily. These trenches should not be more than 9 inches wide and 1 foot deep.

The person using the trench can then squat in such a position as to have one foot on each side of the trench. Squatting in this manner will ensure the whole of the urine and ablution water passing direct into the trench. A wider trench will not be used in this way and is likely to get soiled at the margins. When the trench has been filled up the latrine can be moved a little further on and a new trench dug. In this way, by arranging a simple movable latrine the excreta can be collected and disposed of with safety and without trouble, and the ground so manured can be afterwards ploughed up and cultivated.

Another mode of using these trenches, especially if the latrines are required to be of a more or less permanent nature, is to arrange in connection with them a small filter for the urine and the washings, and partially fill the trenches daily with dry earth which may be removed after the daily defilement. The filter should consist of a small trench 2 feet wide by 18 inches deep, and filled up with gravel and rough sand with some gravel or stones on the top. In all cases the excreta must be covered with dry earth immediately. It is only in this way that the latrines can be kept cleanly and free of offensive odours. Other latrines may have in them small and shallow earthernware receptacles placed in such a manner that they shall receive separately the solid and liquid excreta. A little dry earth is thrown over the solid excreta by the attendant.

In some localities it is impossible to get the people to use trenches. Under these circumstances the compartment of the latrine should be covered with a layer of dry earth and the deposit covered over with dry earth immediately, the whole of the earth mixed with excreta being removed daily and a fresh layer of dry earth put down.

This and the earthernware receptacles are excellent

methods of dealing with the excreta of large encampments of coolies and other large gatherings. The main point is to have some one to attend to the compartments, to see that they are kept clean, that the trenches or receptacles are in proper order, and that the excreta are covered. This primitive system is well adapted for hot countries in the dry season. The latrines may often be open and exposed to the sun with very great advantage ; but during the rains, unless the latrines are protected from the rain, and the latrines or the trenches from flooding, the nuisance will be very great. The compartments of the latrine can be sufficiently protected by bamboo and mat roofings supported on poles, and the trenches can be kept free from the possibility of flooding by sloping the ground immediately outside the latrine in the opposite direction to the latrine.

Chinese Latrines.—In China public latrines are used by the men, and earthenware vases or pots which are kept in a special part of the house, and the contents of which are removed periodically, are used by the women and children. The public latrines in the villages and small towns, where they are not simply platform openings over fish ponds, are well-built masonry reservoirs, not sunken into but raised above the ground with a number of small openings on the top over which the user squats. These simple latrines may or may not be screened. They are primitive in their nature, but there is no difficulty in keeping them clean and free from the objections usually attaching to them. These objections are : First, the offensive nuisance which is created during the emptying of them ; secondly, the reservoirs which they provide for the breeding of mosquitoes ; and thirdly, the attraction which their unclean condition affords to flies ; they are, however, all removable. Thus, with the substitution of a more modern method of emptying these raised reservoirs, the addition of a small quantity of kerosine or petroleum once a week, or even once a fortnight, to prevent them becoming the breeding places of mosquitoes,

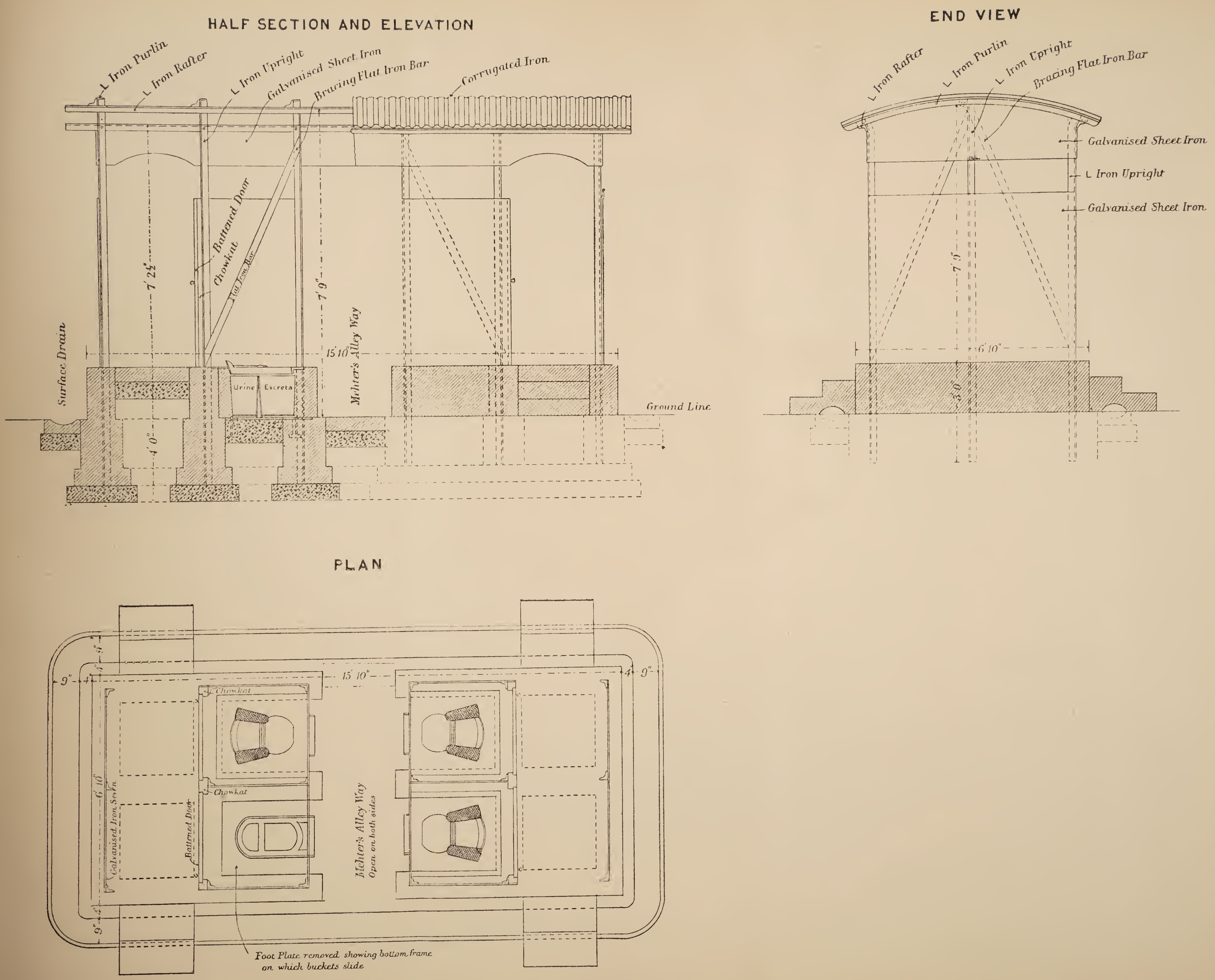
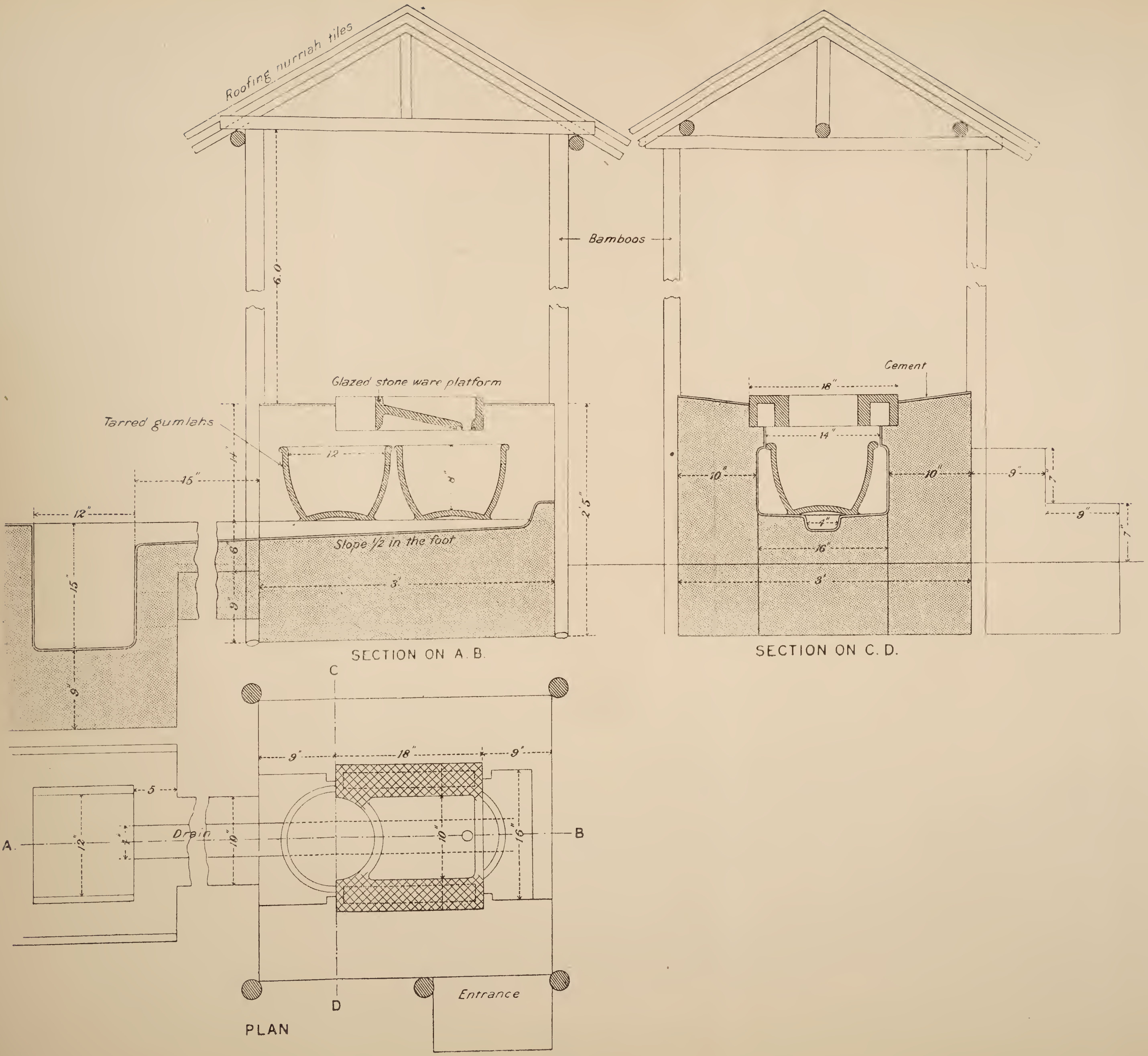


FIG. 32.

Face p. 203.



Roofing nurriah tiles
Bamboos
Glazed stone ware platform
Tarred gumlahs
Slope ½ in the foot
Cement
SECTION ON A.B.
SECTION ON C.D.
C
D
A.
B
Drain
Entrance
PLAN

FIG. 33.

and the keeping of the surface of the deal platforms clean, and washing them with some petroleum once a week, to prevent flies being attracted, a good latrine system can be obtained. In fact the system is much in advance of the ordinary cesspools situated underground, which are seldom water-tight, are subject to floodings, and almost invariably pollute the soil and *sub*soil waters, thus endangering the safety and purity of the water supply.

The keeping of such latrines clean, free of nuisance of flies and mosquitoes is comparatively easy, and is more likely to be carried out by the village and small town authorities, than the regular removal of excreta from ordinary latrines.

More elaborate Latrines.—More elaborate latrines may be classified into those that are so constructed to separate the solids from the liquids, and those that receive both solids and liquids in the same receptacle. In either the chamber which contains the receptacle should have the floor well cemented, and should be water-tight. The supports or walls on which the platforms rest should also be of some impermeable material. The platforms themselves may be of iron, brick set and faced with cement, glazed earthenware, or wood coated over with thick paint (figs. 32, 33). Arrangements should be made by which the scavenger is able to get at the receptacles belonging to the latrines of private houses without entering the house. This is usually effected by having the latrines placed at a little distance from the house against the outside wall of the premises, access being gained to the small chamber underneath the platform from a small door fixed at the back. There should always be pails or other suitable and movable receptacles under the platforms. Sometimes the receptacle is merely an excavation in the floor, and the contents are removed by ladling and transferring to a pail. Such a system should be abolished, for it is most insanitary and an offensive nuisance. Such excavations whether of masonry or not should be filled up, the floor cemented and a movable receptacle, preferably a pail, should be provided.

Fig. 34 shows the Horbury pattern of public latrine, and fig. 35 a double public latrine. They are constructed of galvanized iron and are arranged so that the pails can be removed from the outside.

The Avoidance of Splashing.—Where separation of solids and liquids is not carried out and the excreta are removed in one receptacle, then in order to avoid splashing the pail may be provided with a spittoon-shaped cover lying loosely on it which when fouled can be removed and cleaned. Figs. 36, 37, and 38, show anti-splash pails.

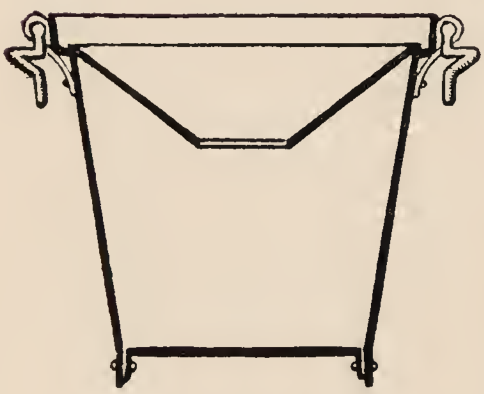


FIG. 36.

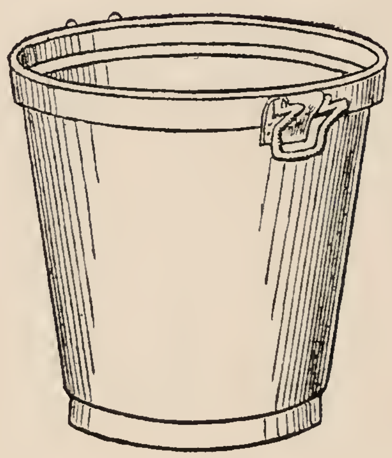


FIG. 37.

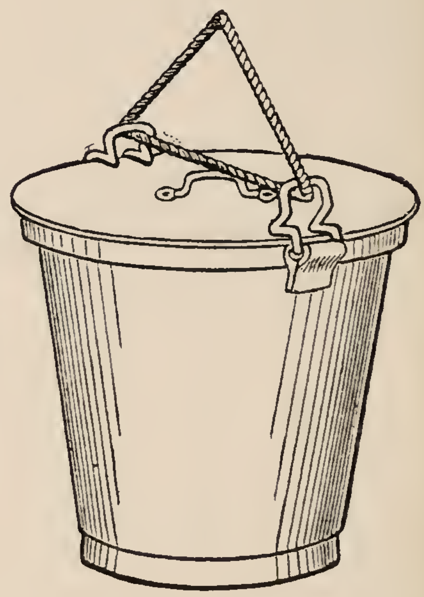


FIG. 38.

Fig. 36 shows the spittoon cover in position. Fig. 38 shows the pail furnished with a lid, and in readiness to be carried bhangy fashion by the mehter to the trenching ground. This is done by the mehter carrying a pail suspended from each end of a bamboo pole slung over his shoulder. This arrangement renders soil-carts unnecessary, and is suitable for small communities. It avoids the transference of the contents of the privy into carts or other receptacles and thus the creation of an offensive nuisance and in this respect is more cleanly and sanitary. On the other hand, it necessitates a double set of pails in order that a clean one shall replace the

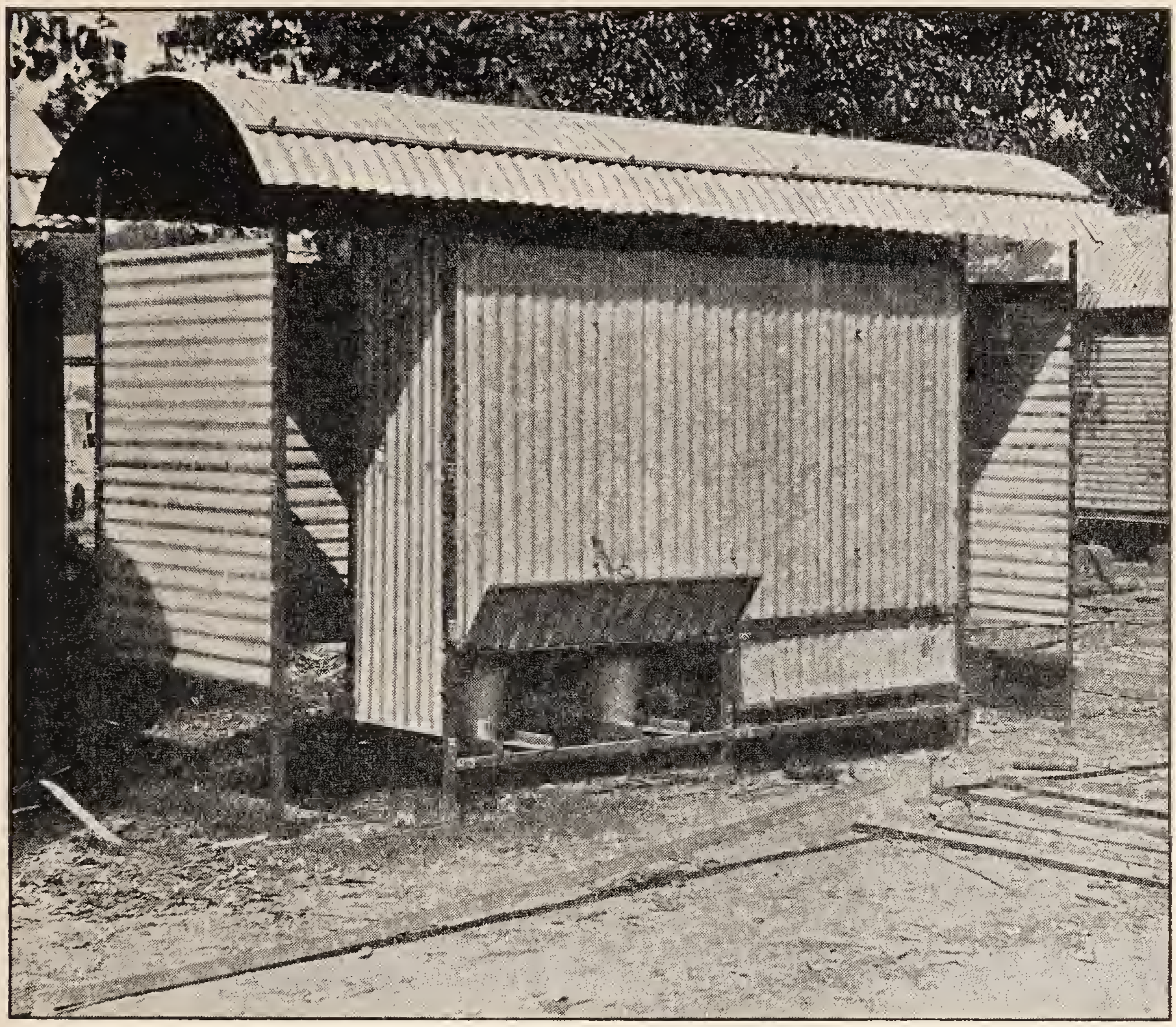


FIG. 34 shows the Horbury Pattern of Public Latrine.

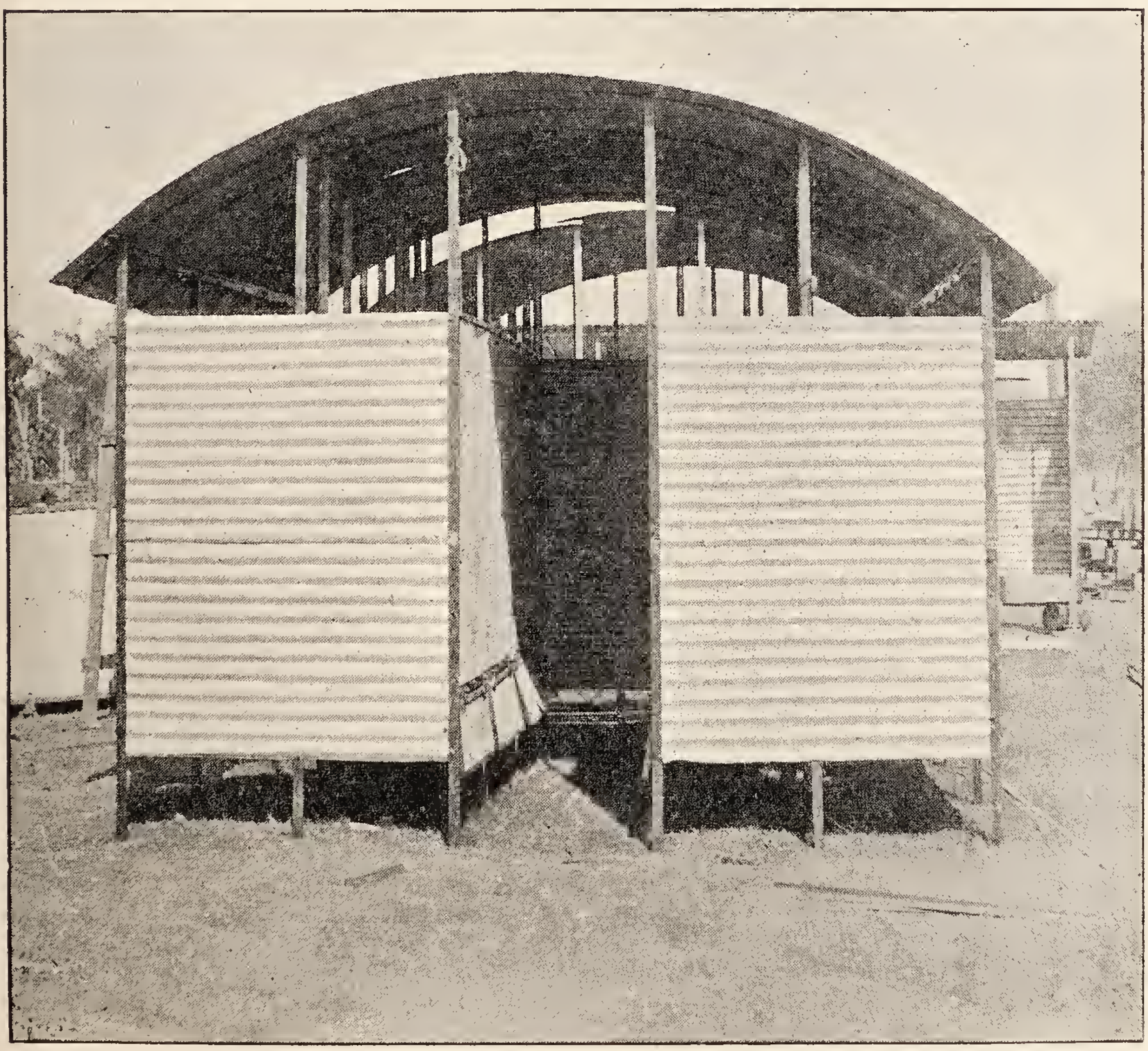


FIG. 35 shows a double Public Latrine.

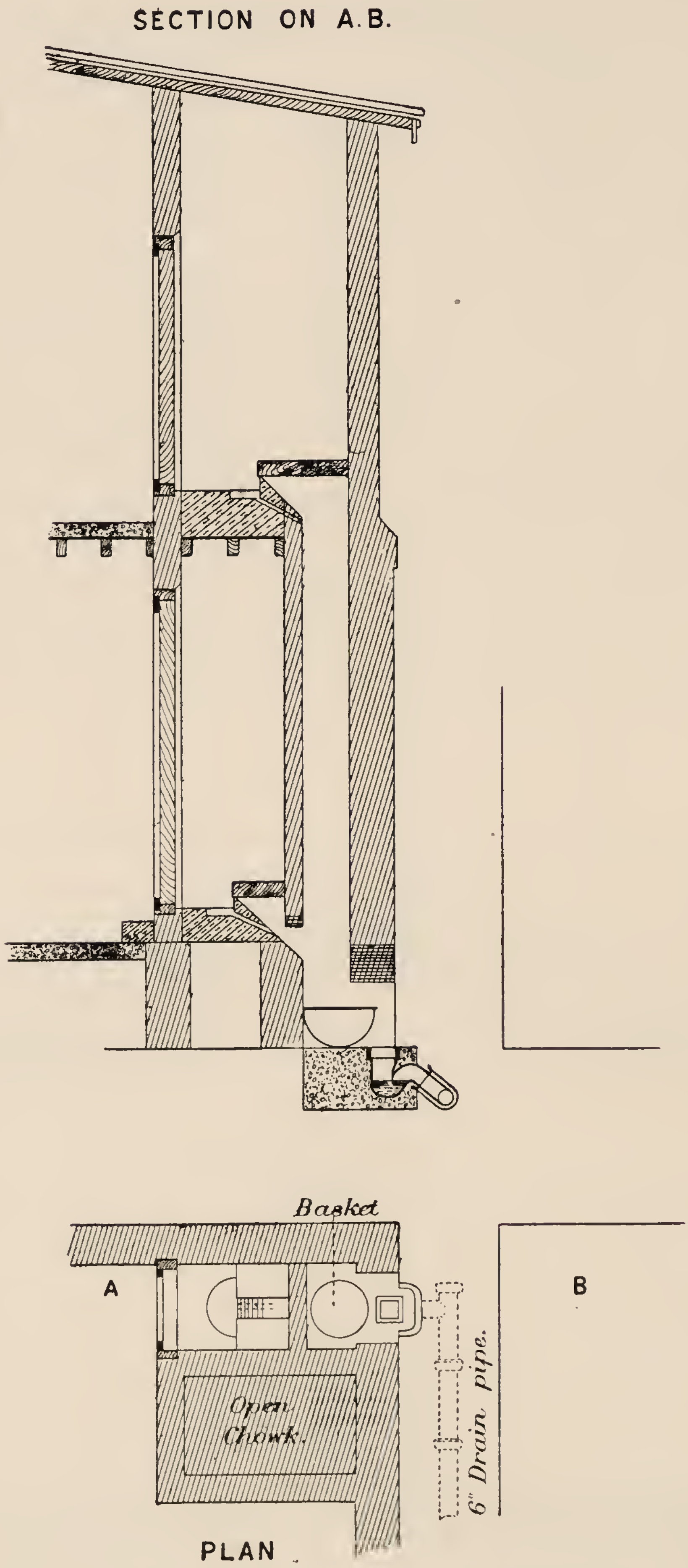


FIG. 39.—Upper story privy in Bombay.

one taken away. The conical cover being loose, can be changed from a full to an empty pail at the latrine.

At one time, and even now in many places, splashing was and is avoided by removing the vault or receptacle as far as possible from the platform of the house latrine. The result is satisfactory as regards the convenience of the user of the latrine, but the insanitary condition of shoots or shafts, leading from the upper part of the house to the place where the excreta finally get deposited, and these depositions, whether in a vault or in the open ground, are most offensive and dangerous, and constitute a nuisance.

Figs. 39 and 40 show some of these kinds of latrines. If by reason of want of water and absence of sewers they cannot be converted into water latrines, and also for other reasons cannot be brought to the ground floor, then they are best dealt with by being converted into an ordinary latrine or latrines, with anti-splash pail immediately underneath the platform and cleansed from a trap-door approached by a verandah from a tower with winding steps sufficiently high for the purpose.

Latrines in which the Solids and Liquids are Separated.—The separation of solids from liquids is a decided advantage in many respects. It allows of the latrines being less offensive, it lessens the nuisance during removal, and it facilitates the application of the excreta to the land. When the urine and fæces are mixed in the latrine, decomposition sets in very rapidly, giving rise to the liberation of ammonia, fœtid organic gases, carburetted hydrogen, &c. It is, therefore, better, if possible, to keep the solids and liquids separate. Urine when passed into water will remain free from smell for a considerable time. When the solids and liquids are mixed, and the carts employed for their removal have to carry the mass some distance to the trenching ground, the contents of the cart get into such a colloid condition that the difficulties connected with trenching are much increased. At the same time the nuisance created by the night-soil cart becomes very much greater.

Different Types : Jail Latrines.—In jails where everything is under strict discipline, and where there is plenty

FIG. 40.—Upper storied privy. 1, Upper storied privy ; 2, Pipes to carry off soil water ; 3, Receptacle in privy vault ; 4, Mehtranee.

of manual labour, the latrines frequently consist of small compartments containing two earthenware gumlahs, one of which receives the fæces the other the urine. Each

prisoner throws over the gumlah containing the fæces a scoopful of dry earth. Ablution is carried out on a special and separate platform in the latrines.

The arrangement of the compartment is given in fig. 49, p. 220. More details as regards the structure of these latrines is given in the chapter on jails.

Chinese Latrines.—In China, in the towns where public latrines are used by the men, the separation of the liquids and solids is very carefully carried out. For agricultural purposes the Chinese accord different values to the excreta, the solid being more valuable than the liquid. For the purpose of separation the following arrangement is adopted in Canton. The excreta fall on to an inclined plane beneath the foot-rest, on which the Chinaman squats. This inclined plane is sprinkled with sand to facilitate the collection and removal of the solids. The urine flows off the inclined plane into the gutter, by which it is conveyed to a sump, where it is received into a moveable vessel. The compartments of the latrine are protected from the rain. In this way the solids and liquids are obtained separately, and in their best condition for manure. The solids, mixed with a little sand, are removed at once by means of a rake and basket; humus instead of sand may be strewn on the floor of the inclined plane with the same result, viz., the separation of the excreta and freedom from nuisance if regularly attended to, and the product removed. The latrine is a simple one, and if a man is on duty always, who does his work in sprinkling fresh sand and removing the fæces and sand in a basket, it can be kept in an inoffensive condition. The latrine should have a concrete or asphalte floor, and although in some places the compartments only are roofed over (as in the Canton latrines), yet it is better where heavy rains are likely to occur for the whole of the latrine to be roofed over, plenty of light and ventilation being provided, as shown in fig. 41, kindly furnished to me by Mr. Osbert Chadwick, C.M.G., which represents the kind of latrines used in Hong Kong.

This Chinese system is one which can easily be adopted in localities where a primitive public latrine is required, and where a bucket system may be too costly. It is certainly more effective and cleanly than would be expected from its simplicity. The solids are taken away to the farms and deposited in pits, covered over with earth, and kept from three to six months when the manure is ready for use. If the manure is insufficiently covered it will assume a watery appearance, and is then not considered to be of value for manure. The urine is not kept for any time, but is used for manurial purposes shortly after collection.

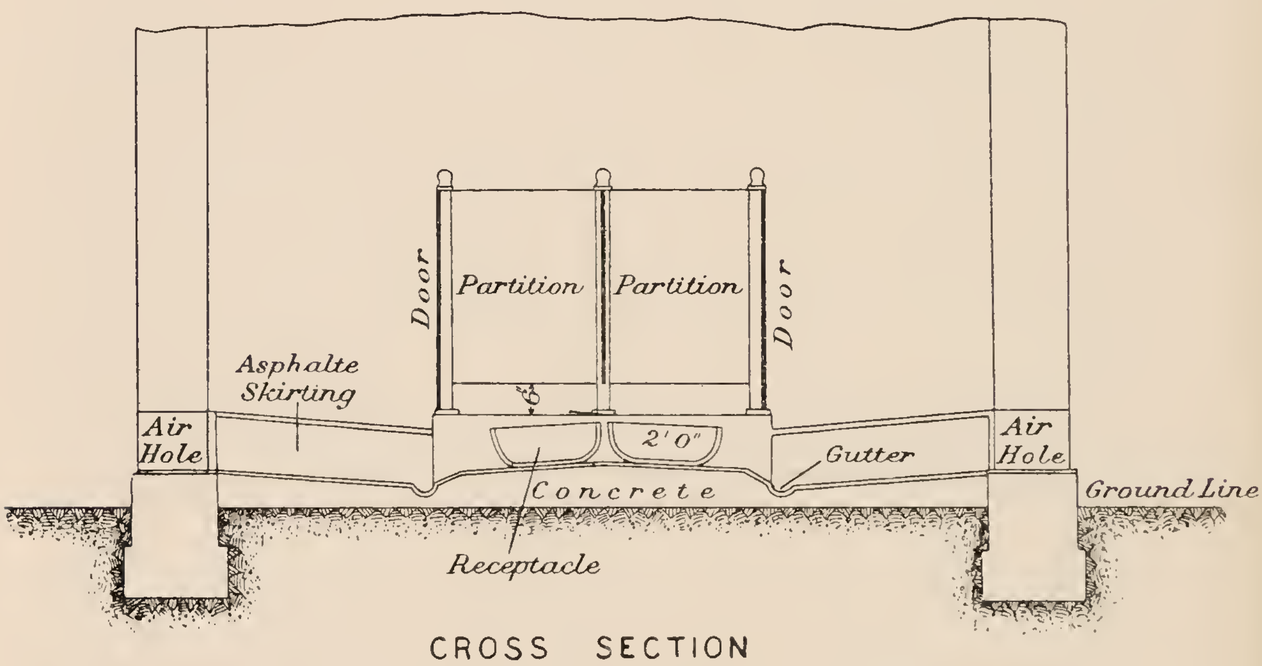


FIG. 41.—Latrine used in Hong Kong.

Indian Types.—In India the separation of the solids and liquids is often effected by so arranging the platform of the latrine on which the person squats that the urine and washings are conducted by a conduit or pipe to a receptacle situated below the front part of the seat or at a convenient site elsewhere inside the latrine, and that the solids fall direct into another receptacle immediately below the seat. The receptacle requires to be sufficiently near the seat to prevent the possibility of the excreta falling anywhere else but inside. The receptacle may be a galvanized pail, which is somewhat expensive, or

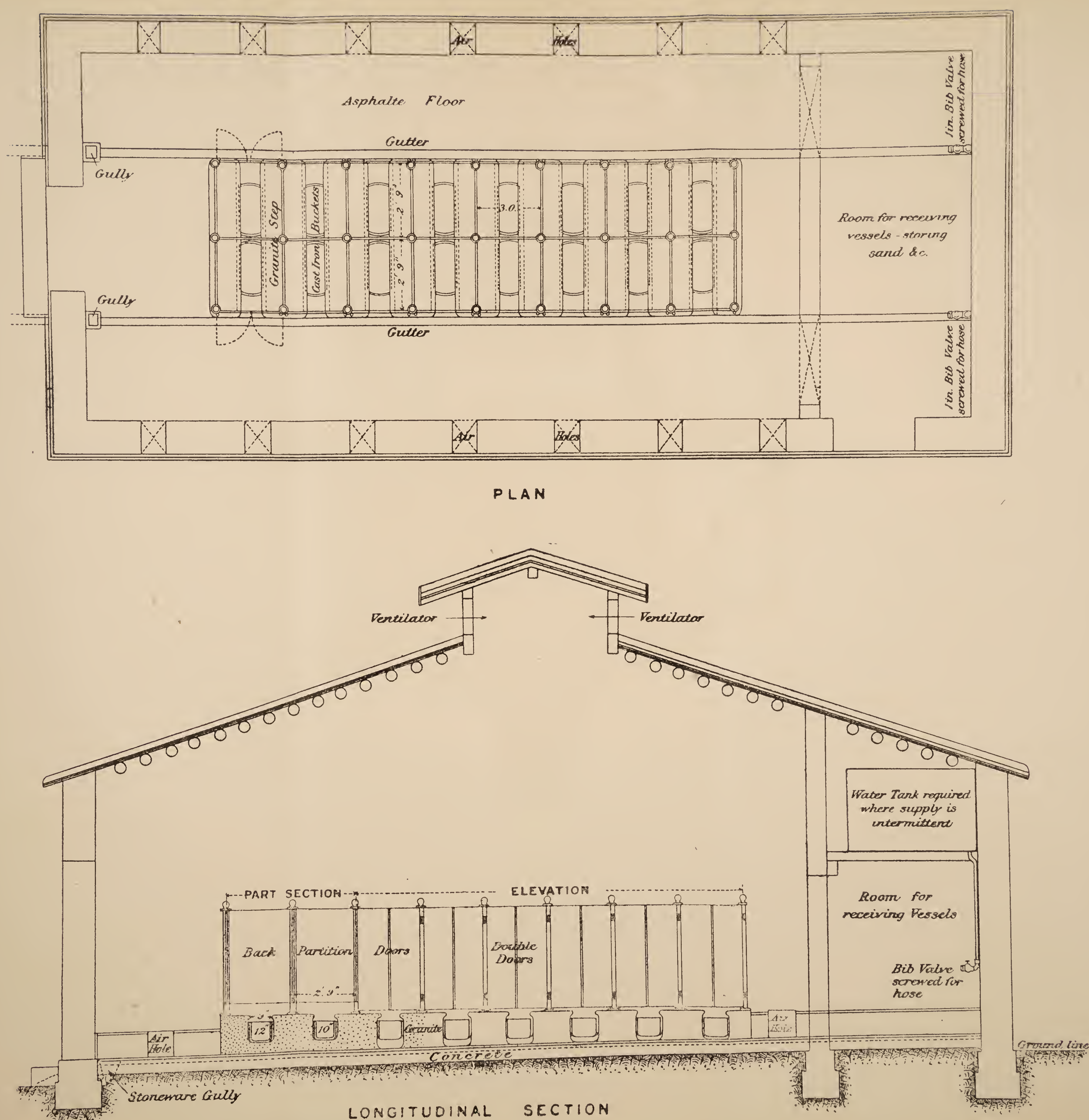


FIG. 41.—Latrine used in Hong Kong.

Face p. 210

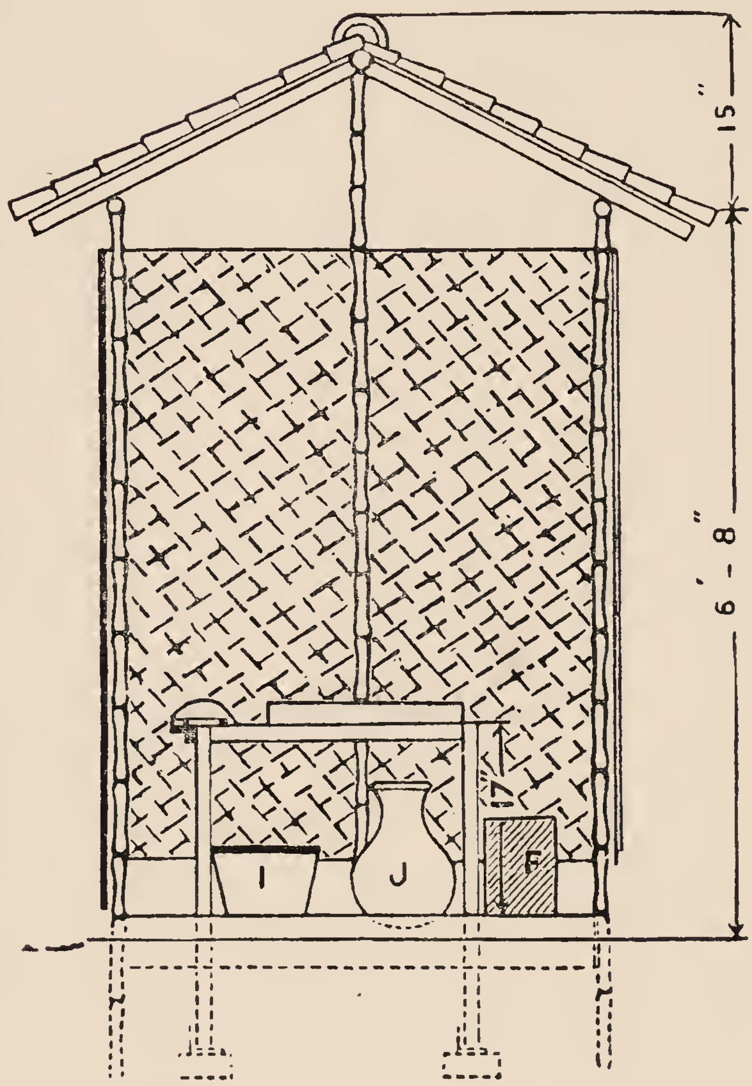
a tarred earthenware vessel. Wooden pails or tubs are not adapted for the purpose, but if no others are obtainable they should be tarred. In hot countries the excreta, both solid and liquid, should be removed at least once in twenty-four hours, and twice a day if possible. The advantages of the separation system, in addition to those already mentioned, are that there is not the same risk of the receptacles or pails overflowing when used by a large family, and the consequent insanitary condition of the latrine produced by the accident; and the user of the latrine is not subject to splashing, which is not an infrequent occurrence when the combined system is used, that is, when solids and liquids pass into the same pail or receptacle.

In order to avoid this splashing the users often squat on parts of the latrine other than over the opening above the receptacle or pail, and thus the latrine becomes very filthy. Separation also facilitates trenching or incineration. It allows of the immediate and ready disposal of the liquids for irrigation and supplies the solids in the best form for trenching.

Specially designed platforms are constructed for the separation process both for the privies of private houses and for public latrines. These platforms may be made of cast iron or glazed stoneware, the latter being the more sanitary. The following plans show the construction of latrines of this kind. Figs. 42, 43, 44 and 45, represent the Oriental pattern.

Oriental Latrines.—Figs. 42 and 43 are cheap types of oriental latrines and suitable for huts.

In fig. 42 the platform consists of two side pieces in cast iron and a central portion, E, a deflector made in glazed stoneware kept in position by an iron strap bolted underneath. The whole platform is supported on an angle iron framework. The structure is built on a small masonry plinth faced with cement, and may have a masonry footstep, F, on which to mount to the platform. In fig. 43 the platform and deflector are metallic,



Elevation (Section across A B).

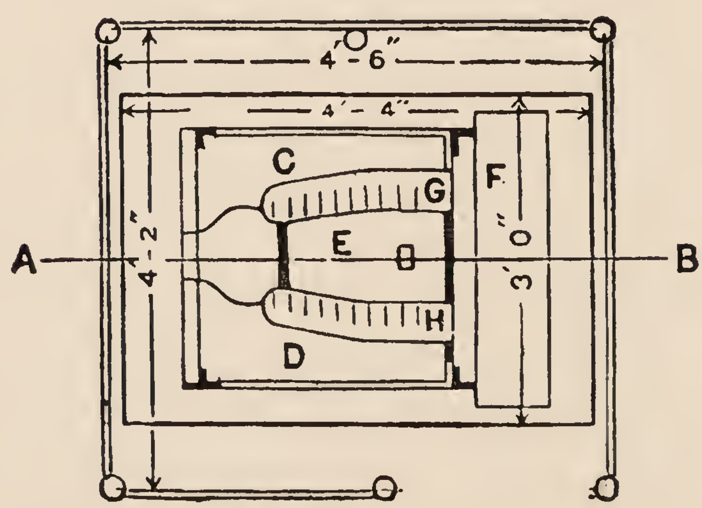
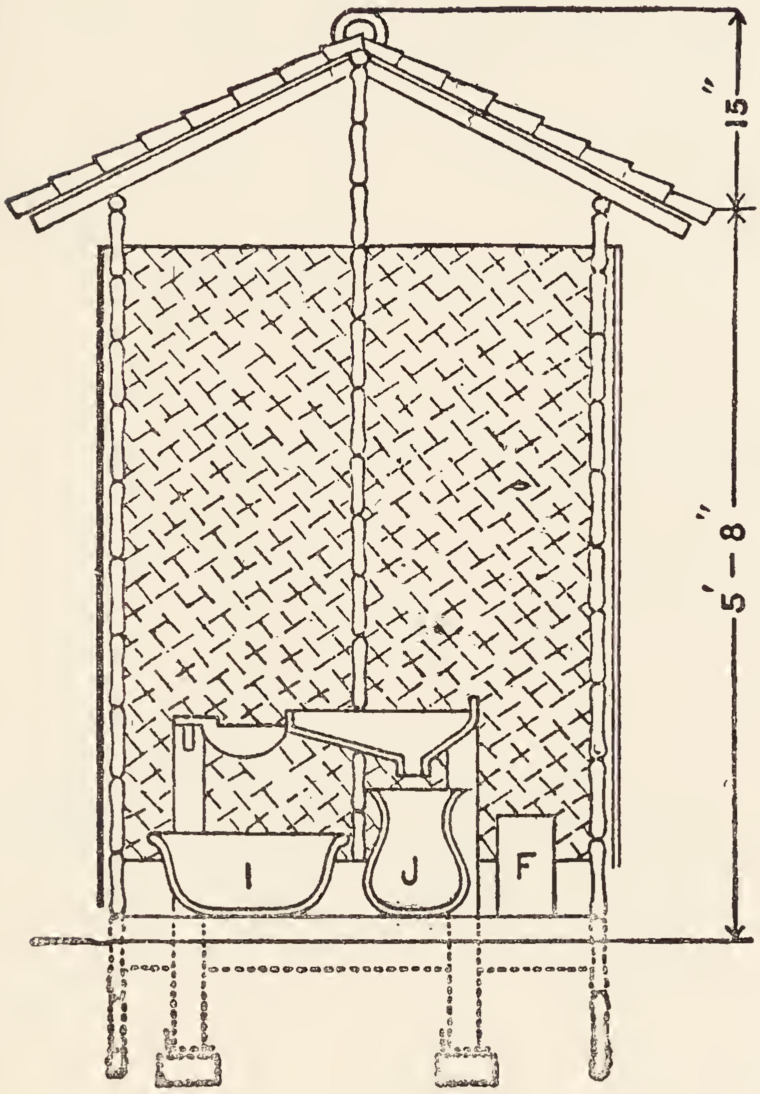


FIG. 42.—Plan of simple type of Oriental latrine.



Elevation (section across A B).

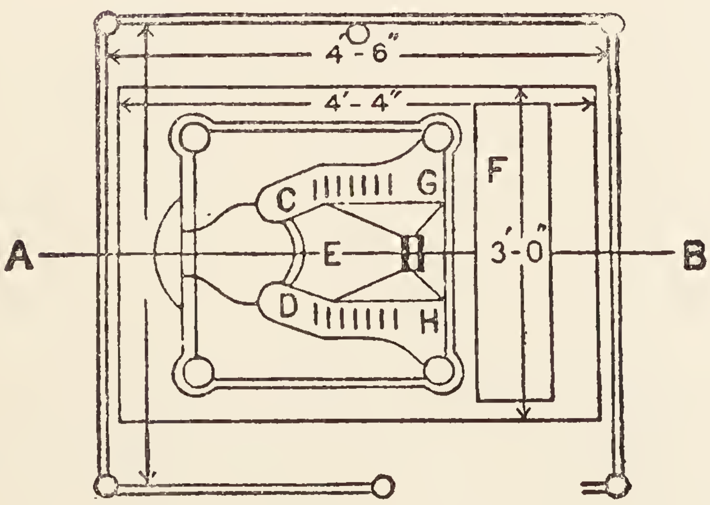


FIG. 43.—Plan of simple type of Oriental Latrine.

and made in one piece of cast iron. In both figures I is the vessel to receive the fæces, J, that to catch the urine and ablution water. The platform is supported on

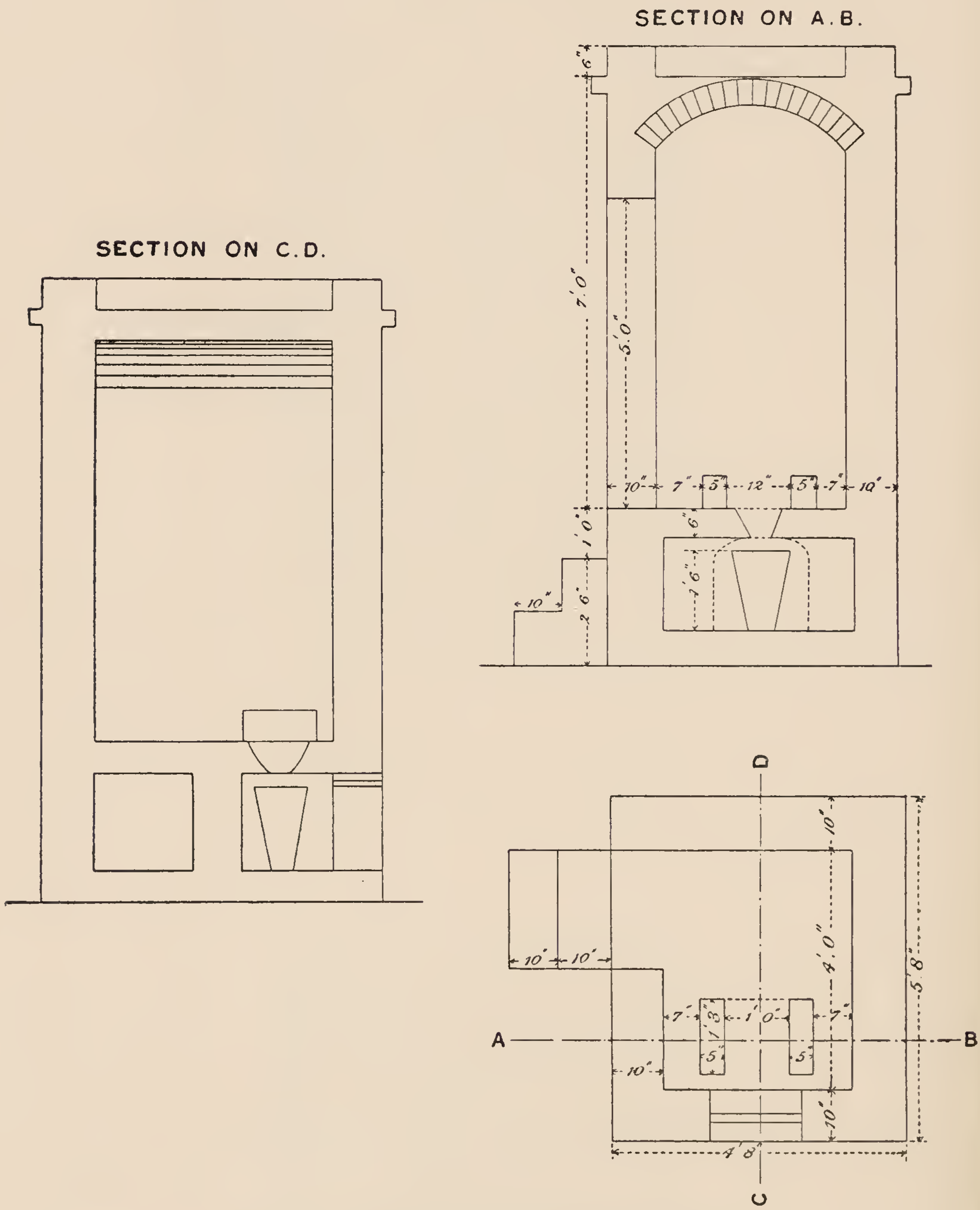


Fig. 44.—Plan of Latrine for Private House.

four vertical bamboos to act as legs or pillars. When well-seasoned bamboos are selected and well tarred they last a long time, and can always be renewed when required.

For private houses of a better class, the designs of fig. 44 represent a latrine that is suitable. Such a latrine is usually placed in the courtyard outside the house. Instead of being made of cast iron, the platform is of glazed stoneware embedded in cement. The latrine with its impervious surfaces can be always kept clean and in a sanitary condition.

In fig. 45 the platform and support consist of glazed stoneware.

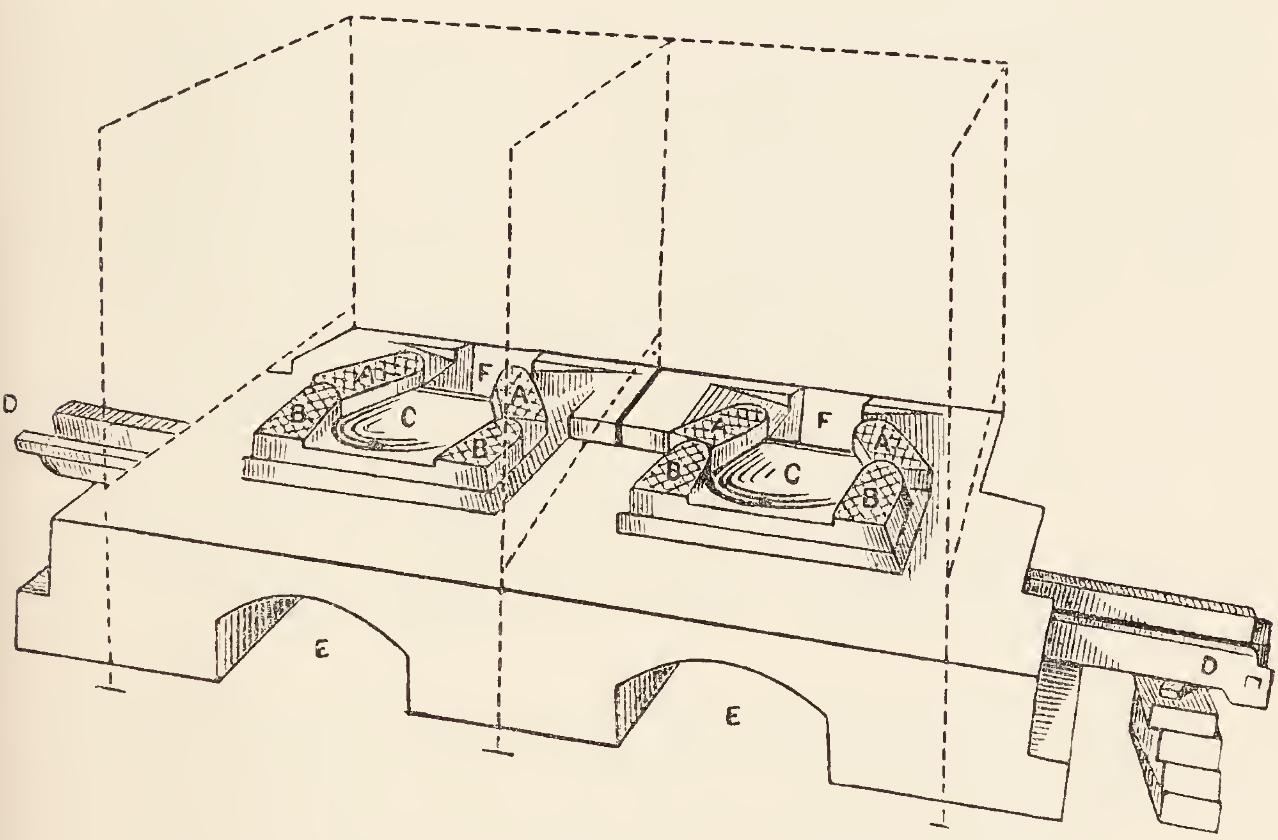


FIG. 45.—Double Latrine with Glazed Stoneware Platforms.

A A are the foot-rests occupied by the user. B B are those to which he moves forward when washing. C is the urine and washing deflector. D the pipe conveying the liquids away. F is the opening over the pail which receives the fæces. The liquids are collected in another pail or receptacle properly protected from rain and flood water. With a proper structure over it, a latrine of this kind can be used in private houses. It is also suitable in large installations for public latrines and ranges of latrines such as are required in industrial and large institutions.

Fig. 46 gives a plan of an installation for a public latrine with six seats.

A is a glazed stoneware drain which conveys the liquids and washings to a covered reservoir B. The whole latrine is so protected from the rain that no rain

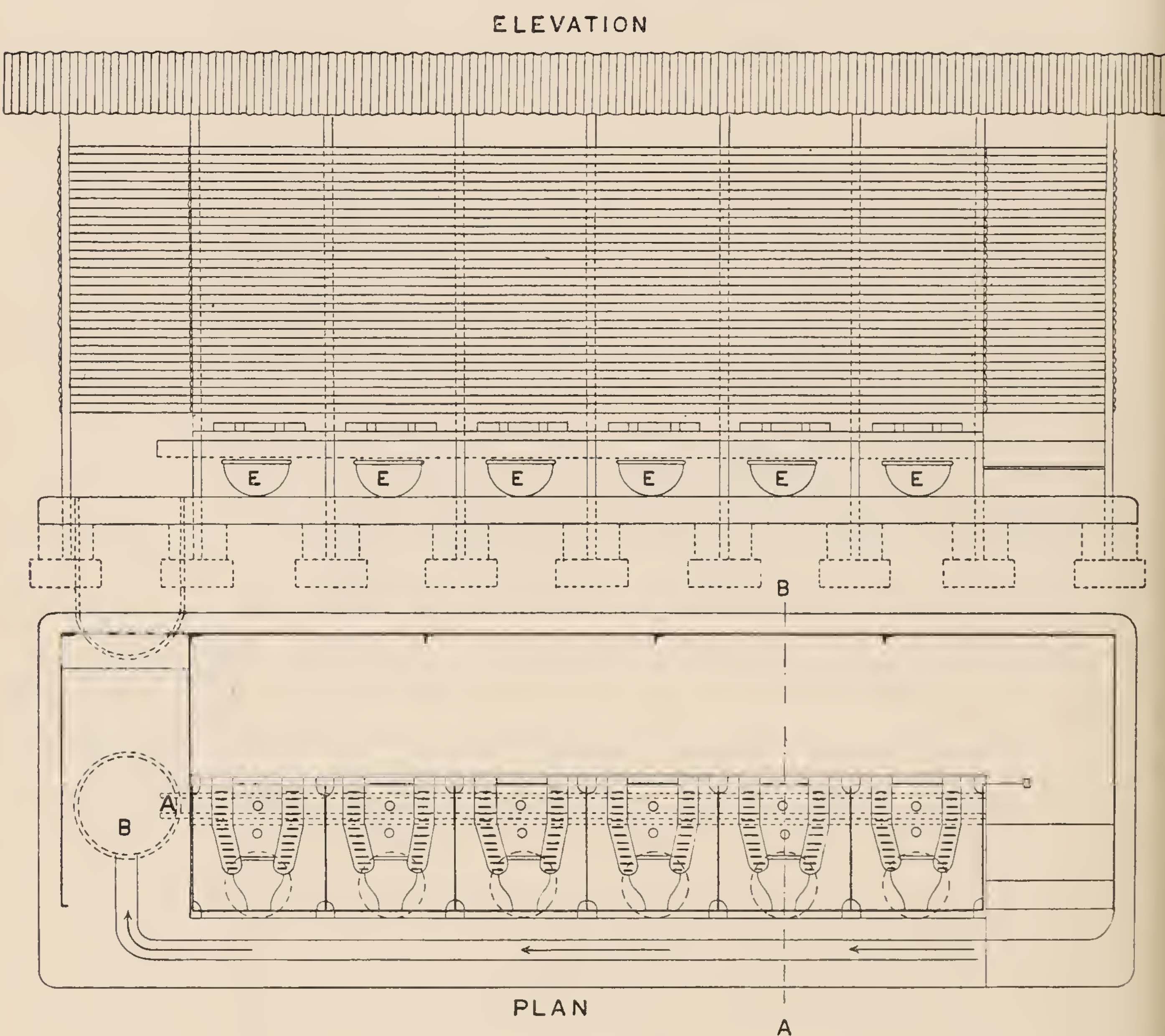


FIG. 46.—Public Latrine with six seats.

water can flow into the reservoir B. The drain (marked with arrows in the plan) is to carry water into the reservoir when the latrine is washed down.

Macfarlane Latrines.—Other latrines of a similar type are those of Macfarlane, which are constructed wholly of cast iron. Almost every form can be obtained, and

they are well adapted as public latrines for streets, railways, works, factories, schools, institutions, &c.

The patent foot-rest dry pan closets are constructed to insure the complete separation of the fæces and urine, and the collection of the former or of both in convenient-sized pans, so as to be easily removed and readily available for their respective uses, either agricultural or

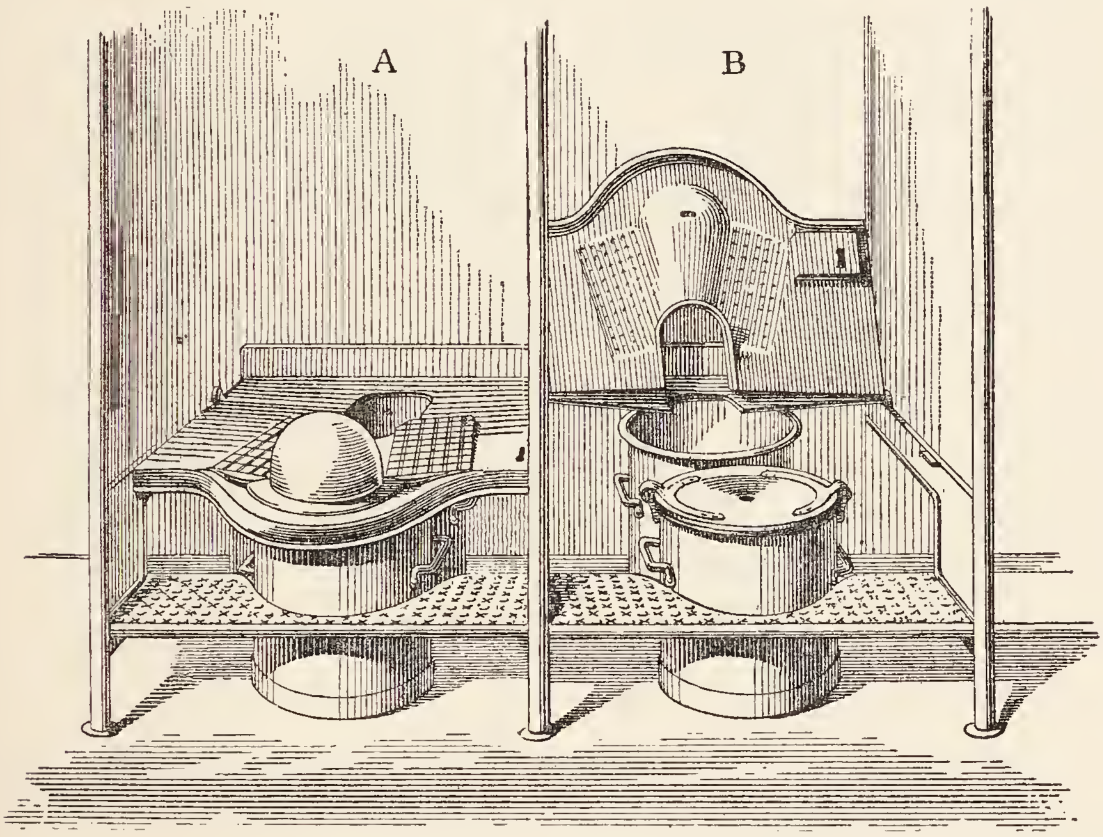


FIG. 47.—Patent foot-rest dry pan closet.

chemical. By one arrangement the urine and washing water is discharged direct into a drain or tank, and only the solid excreta collected in the pan. By the other arrangement, the fæces is collected in one pan and the urine in another (fig. 47). The urine pans have each a tight-fitting cover fixed on while the pan is in use, and only requiring to be removed for emptying or cleaning. The pans receiving the fæcal discharge in either arrangement are prepared for similar tight-fitting covers to be applied before removal of pans (various types of pans are shown in fig. 48). By these means the full pans

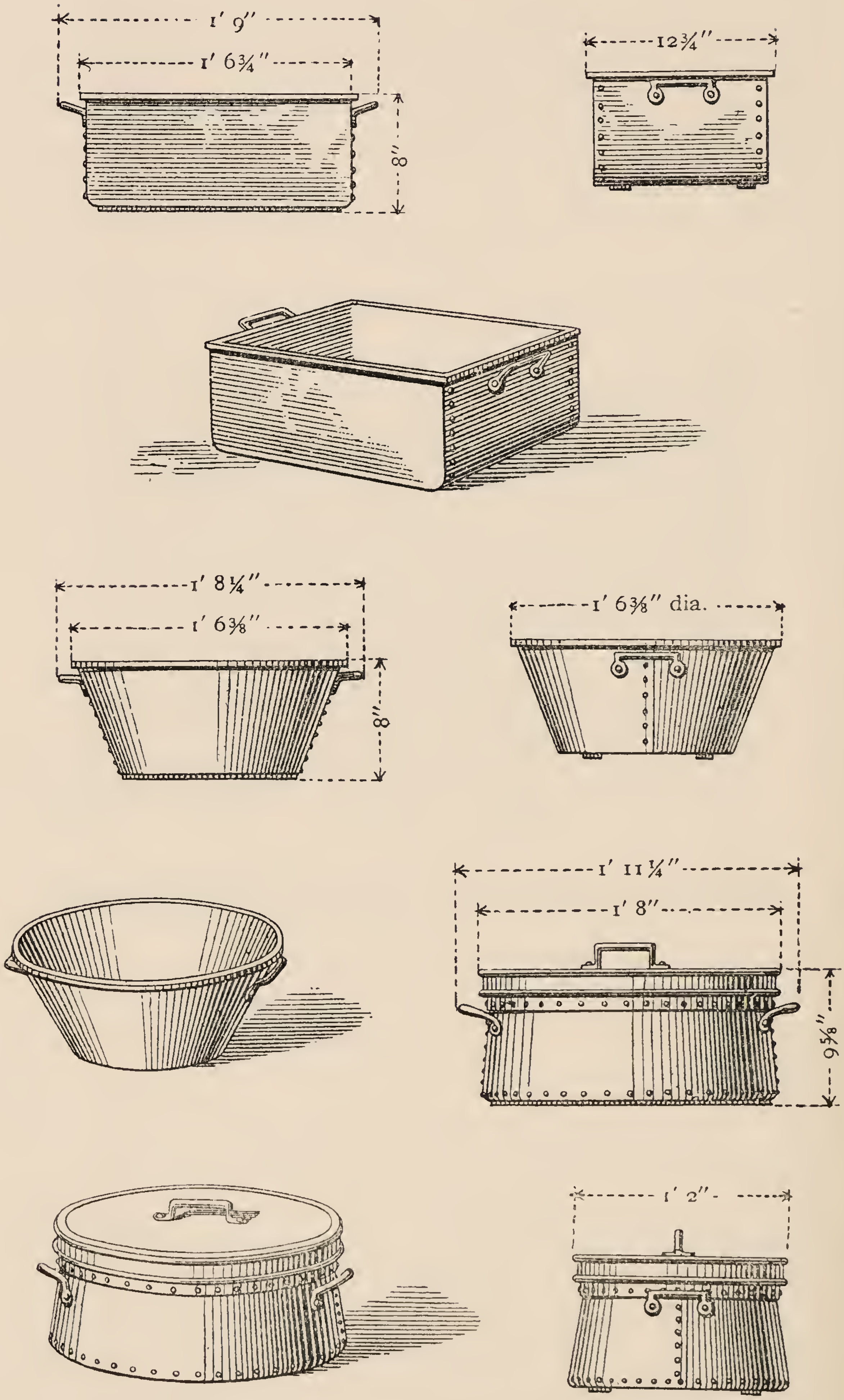


Fig. 48 shows various types of Soil Pans in use.

can be removed and replaced by empty ones, and the full pans carried or carted away. The iron foot-rest plate is hinged so that when lifted it rests against the back wall, giving the attendant easy access to the pans for removal at stated times, but a lock on each is supplied to prevent tampering by others. Guides are also provided to enable the attendant to place the pans in proper position. On the hinged foot-rest plate are raised and roughened surfaces for the feet, making it difficult to stand or squat on any other part, and in front is a concave splash plate to confine the urine to its proper channel. The contents of the pans are almost entirely hidden from view.

The attached diagram (fig. 49), shows the various forms in which this type of latrine can be supplied with divisions and screen walls.

The Commode.—In the case of Europeans the commode is the best sanitary appliance. Placed in the bathroom it can be emptied at once by the servant into a covered iron receptacle kept in an outhouse and brought back to the bathroom clean. The iron receptacle is emptied and cleaned at least once in twenty-four hours, the contents being taken by the scavenger in a soil cart or in soil pails. Sometimes earth closets are used and sometimes pail closets, ashes or sawdust being used to cover the excreta. In a dry earth closet of vegetable-eaters, $2\frac{1}{2}$ lbs. of earth instead of $1\frac{1}{2}$ lbs. are required for deodorization. Every kind of dry earth is not suitable for deodorizing purposes. The best are loamy surface soil, vegetable mould, brick earth and dry clay. Sand, gravel and chalk are not good for the purposes of deodorization and should not be used. The earth should be first dried, then sieved, exposure of the earth to the sun being the best way of drying it. Great care has to be taken if the earth is dried by fire not to overheat it, for should this be done it will no longer be a "living" earth but will have been sterilized, and no longer contain the ferments and micro-organisms

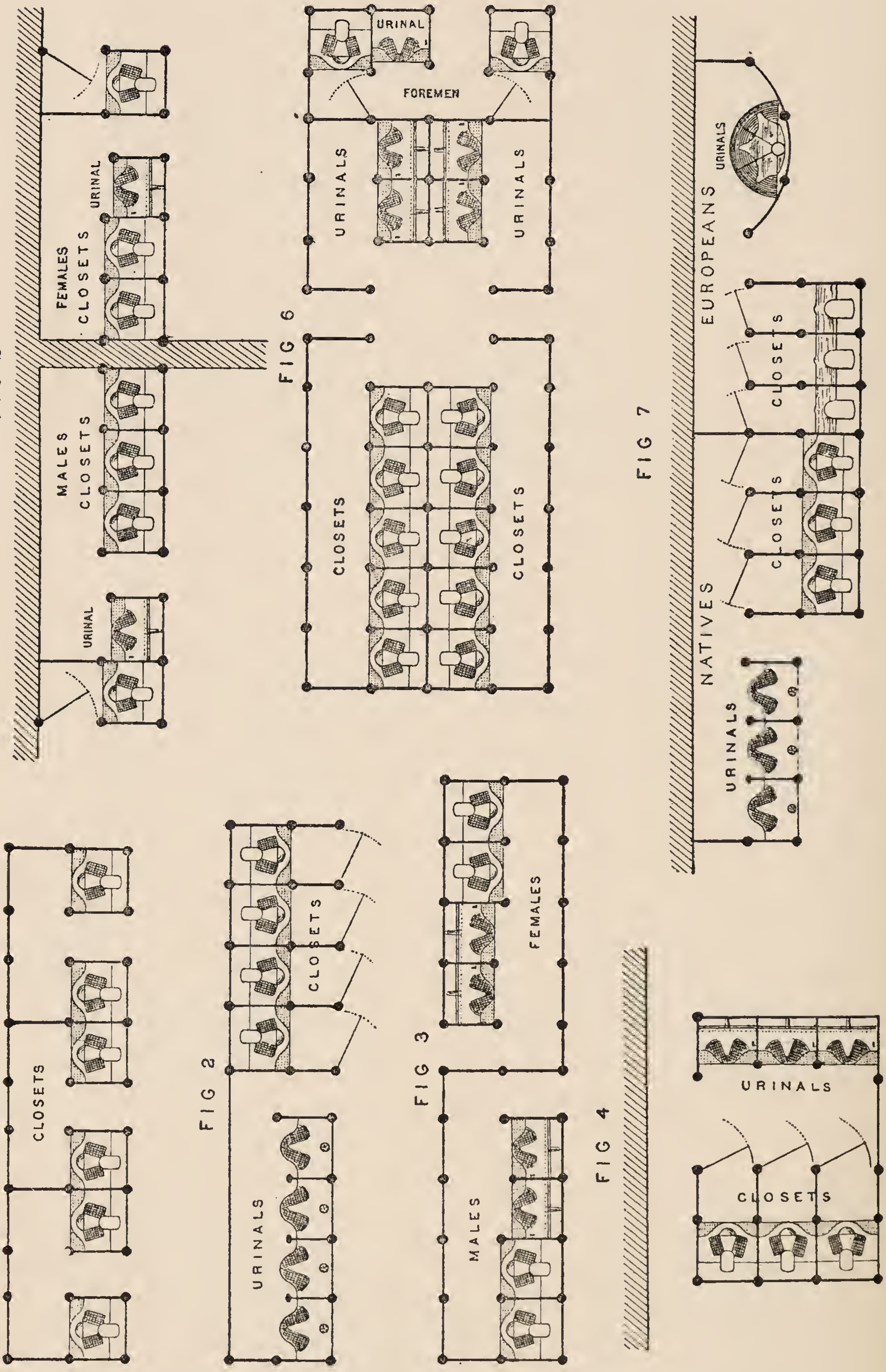


FIG. 49.—Various methods of arranging compartments of latrines.

which give it the property of acting on the excreta; overheating renders the earth useless for the time being. Arrangements are usually made that the scavenger should be able to get at the receptacles belonging to the latrine without entering the house. This is generally effected by having the latrines placed at a little distance from the house against the outside wall of the premises, access being gained to the small chamber underneath the seat from a small door fixed at the back. The chamber which contains the receptacles should have its floor and walls well cemented, and should be water-tight. The platforms for people who squat are, as already stated, made of iron, brick set, and faced with cement, glazed earthenware, or wood coated over with thick paint.

The Removal and Disposal of Sewage.

The Use of Pails and Carts involved.—The removal and disposal of sewage from a town or village that is not sewered involves manual labour and the employment of special pails or carts, with men or, as in India, men and women of the mehter caste, to do the work. It also involves the provision of suitable land for the trenching of the sewage. Incineration is another mode of disposal of the sewage, but its application is limited. The removal may be effected in several ways, and the number of pails and carts required, and also the manner of removal, will depend on the system adopted.

Different Systems of Removal.—If a system of pails for each latrine is in practice then the pails after being covered may be taken direct to the trenching ground, clean and fresh pails being at the same time substituted for those taken away. The cleansing and disinfection of these pails would be done at the special depot for that purpose at the trenching ground. This system is undoubtedly the best, and if carried out daily and the pails are thoroughly cleansed and disinfected it is as satisfactory as hand labour will allow. For public

latrines under municipalities and railway companies, and also for latrines in mills and other large works under private companies, it is usual to have three sets of pails or receptacles for each latrine in order that while one set is in use, another set will be on their way to be emptied at the trenching ground, and a third set of clean receptacles is in reserve at the latrine. In other systems the contents of the latrine vessels are emptied direct into a special pail or cart. Both create a nuisance, particularly the emptying into the cart, and the latrine vessels are never properly cleansed. This system should be abolished whenever possible. Sometimes in order to mitigate the nuisance occasioned by the cart going from house to house it is kept at a special depot, and the latrine vessels are emptied into a pail, and then the contents of the pail are emptied into the cart at the depot, where arrangements are provided for cleansing and disinfecting the pails. The depot will probably contain several carts, the nuisance for some distance round these depots during the operations is very great, and the depot should certainly be well removed from inhabited houses. In the absence of removal of the pails in covered carts, as effected in Penang, the pail system worked by each man removing two pails by suspending one at either end of a bamboo pole, and then slinging the pole over his shoulder and taking it direct to the trenching ground is by far the most cleanly and satisfactory system. He begins by having two clean pails to replace the two he takes away. In places where it is convenient the pails can be put into trucks on light tramway lines and conveyed to the trenching ground. This of course is a quicker and better transport than the man with the bamboo pole mode of carrying the pails, or than the man carrying one pail on his head. Another method is to have specially constructed carts in which the covered pails are placed and drawn by bullocks or horses to the depot, or trenching ground. The kind of pail varies in different places. It may be a wooden bucket

well tarred inside, and with a good cover as in fig. 50, which shows the kind used in Calcutta, or it may be a pail with cover as shown in fig. 38, p. 205 or a bucket which is used in Bombay. The size should be uniform and the capacity at least one cubic foot.

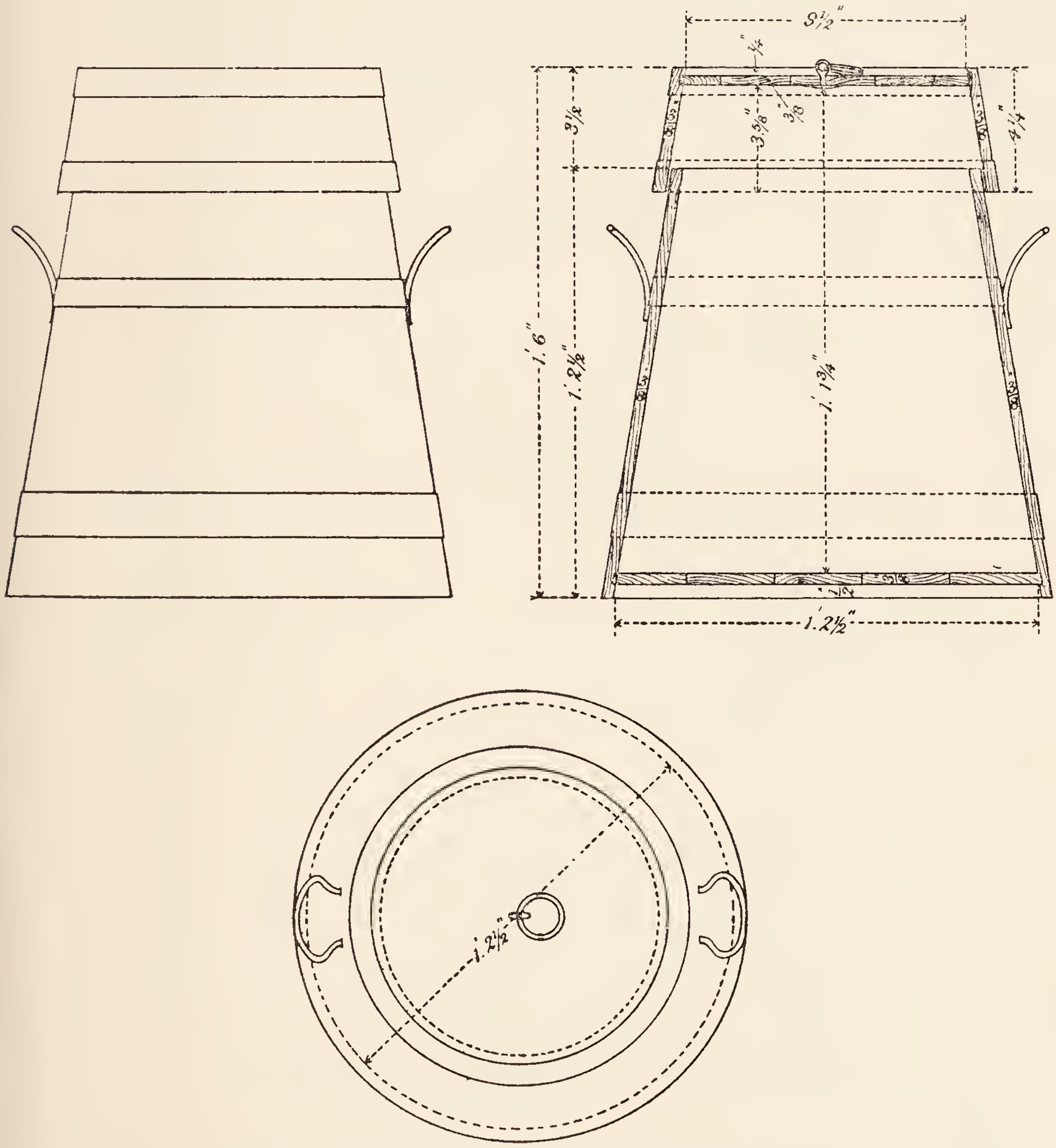


FIG. 50.—Night-soil Bucket used in Calcutta.

Carts.—Of the different kinds of carts that having a receptacle suspended from the frame of the cart by trunnions is the best. It is so hung on the axle that it can be easily tilted over and discharge its contents where

required. Figs. 51 and 52 show the kind of cart used in Calcutta, fig. 53 is a photograph of Crowley's night-soil carts, showing mode of emptying; fig. 54 shows another kind of a cylindrical shape. Carts having a discharge opening at the lower part as in fig. 55, which is closed by a valve screwed or otherwise fastened, should be avoided. The valve soon gets out of order and leaks, the result being pollution of the roads through which the cart passes.

END ELEVATION

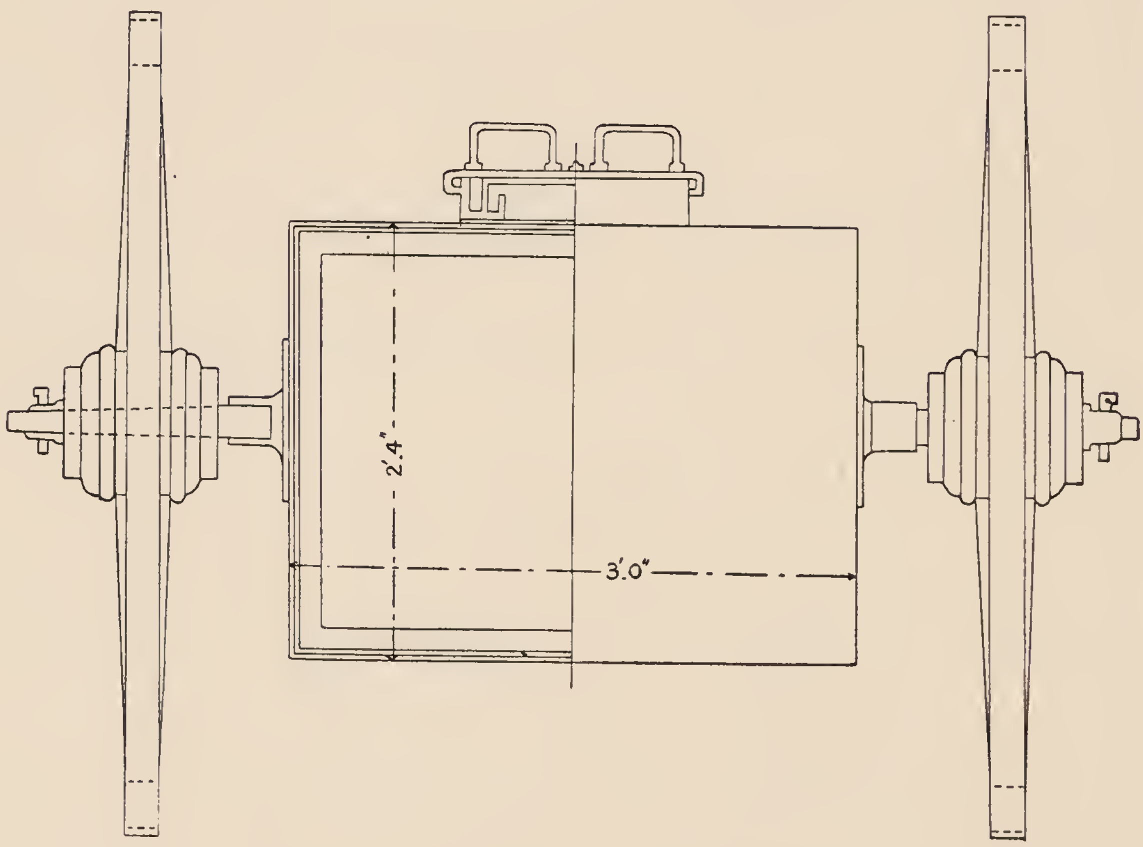


FIG. 51.—Night-soil Cart, Calcutta.

The carts generally have a capacity of 12 cubic feet. To calculate the number of buckets or carts required to remove the excreta of a village or small town, the average amount of solids and quantity of liquid passed daily by each person, the number of the inhabitants, the capacity of the bucket, or of cart, and the number of trips that can be made by those who convey the excreta

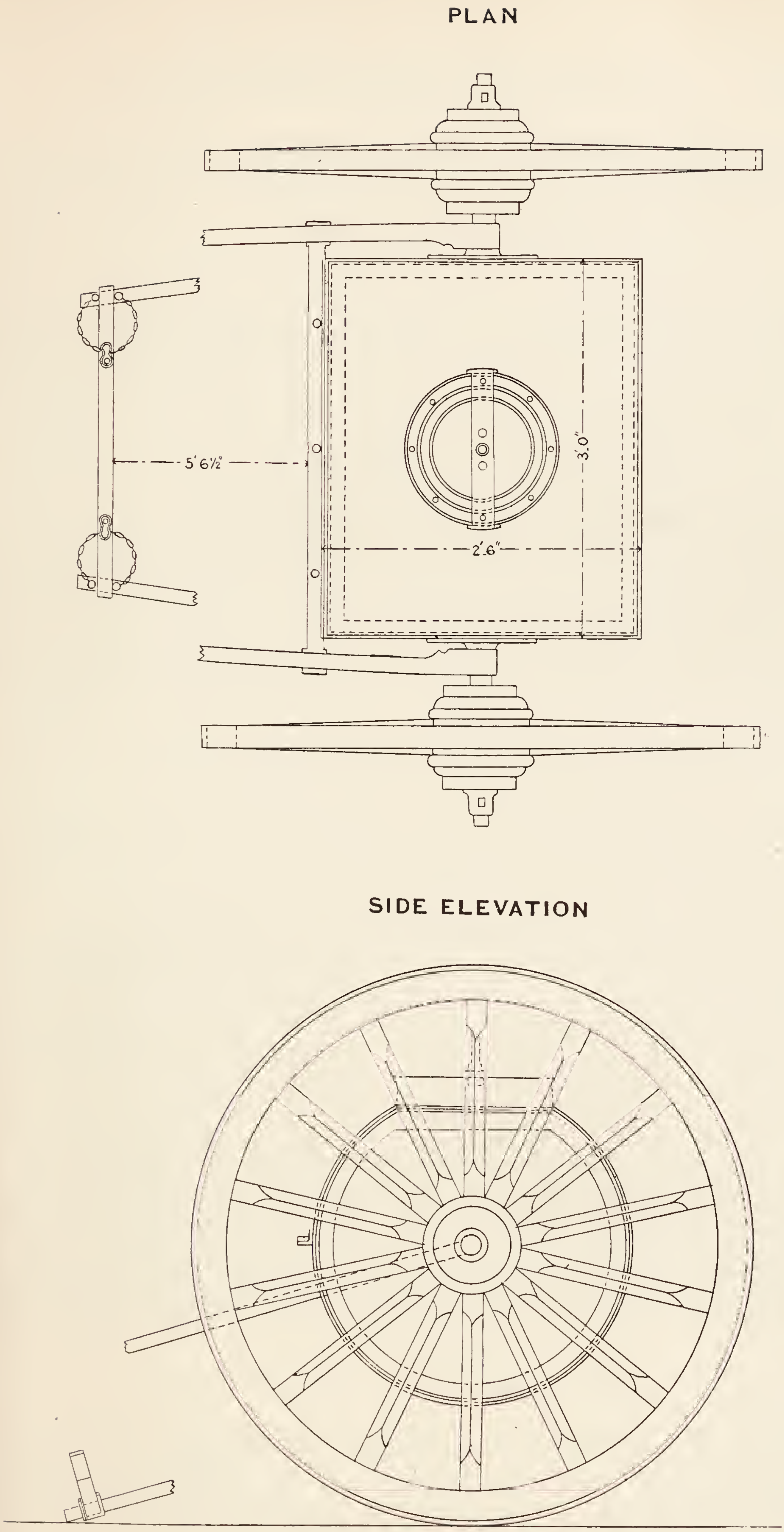


Fig. 52.—Night-soil Cart, Calcutta.

in buckets or carts to the trenching ground must all be taken into account.

The carts should be thoroughly cleansed both inside

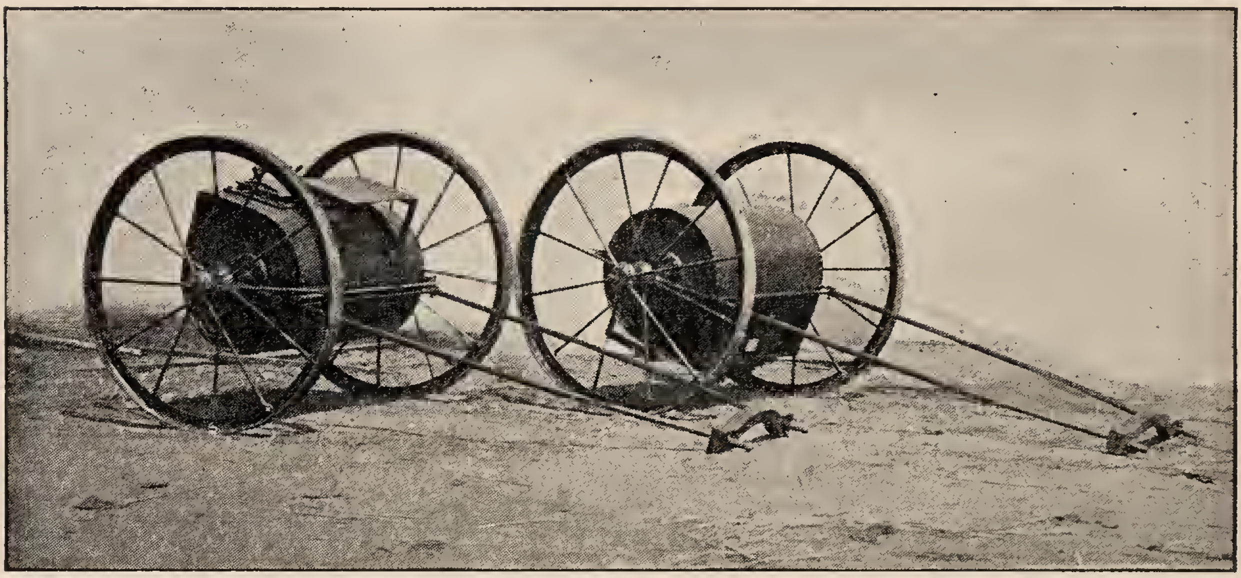


FIG. 53.—Crowley's Night-soil Cart. That on the right is inverted for emptying.

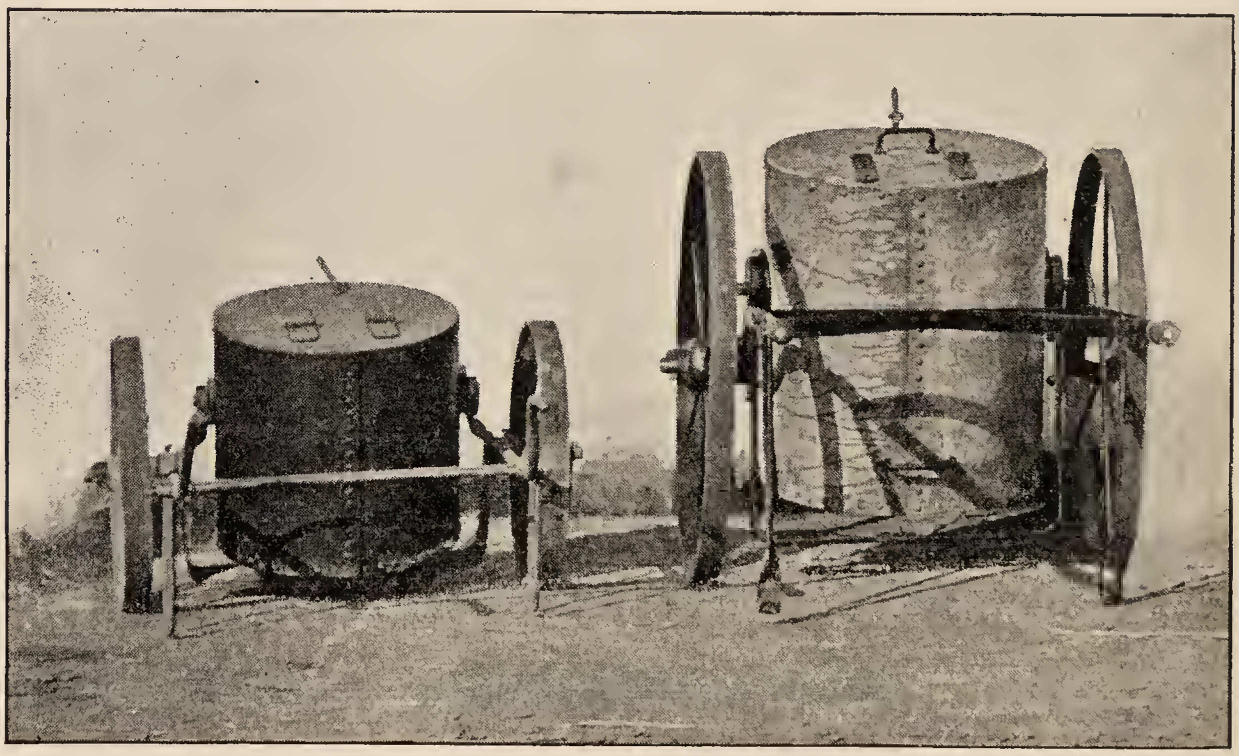


FIG. 54.—Night-soil Cart. Cylindrical pattern.

and outside at the trenching ground depot by a liquid disinfectant such as cyllin, izal, or kerol. It is this absence of cleansing and disinfection of the carts, pails

and buckets every time after they have discharged their contents at the depots or trenching ground which largely brings discredit on the system, and which causes this mode of removal and disposal of excreta liable to spread disease. The lids closing the openings in the carts should also be so constructed that when in position they allow the use of earth or disinfectant to seal the rim and prevent offensive smells escaping from the cart when it is full.

FIG. 55.—Night-soil Cart with discharge valve opening underneath.

By far the best arrangement in larger communities where the night-soil has to be removed manually is for a tramway to be laid down from the depots and the pails to be put on trucks and taken by rail to the trenching ground.

In some towns such as George Town in Demerara, the water-closets discharge from the larger houses into underground cesspools, which consist of iron tanks of 400 gallons capacity, or of cemented pits. These cesspools

are emptied by a hose attached to a large barrel cart, a pump attached to the cart pumps up the contents and offensive gases are burnt by passing through a small fire on top of the barrel. All cesspools of this kind should have their ventilators and other openings protected by wire gauze of at least 100 meshes to the square inch in order that they shall not become breeding places for

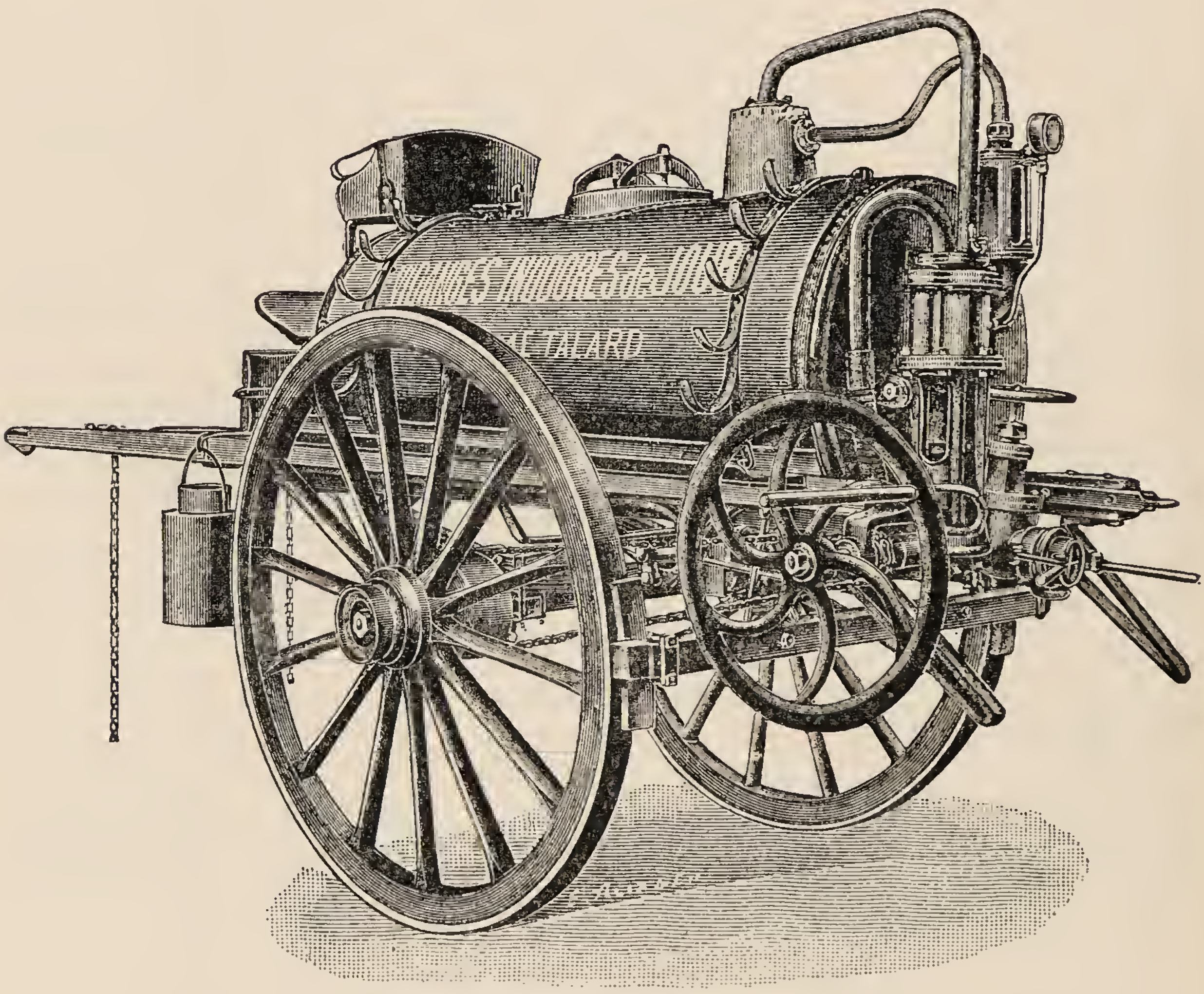


FIG. 56.—Tonne Vidangeuse Pneumatique Automatique.

mosquitoes. Should this happen, a quantity of petroleum should be poured into the cesspool at least once a fortnight to destroy the larvæ and prevent mosquitoes laying their eggs in the sewage.

In Egypt, the cesspools are cemented tanks and are emptied in a similar manner by the Talard system which effects the operation without nuisance.

The most recent application of this system is the

"Tonne Vidangeuse Pneumatique Automatique" (fig. 56), which consists of a cart with barrel tank to which is fitted the necessary pipes and pneumatic pump, and to which also is attached a small furnace for burning the gases drawn off from the cesspool during the process of emptying.

Disposal of the Excreta by Trenching.

Essentials. The Site of a Good Trenching Ground.—Great care has to be exercised in the selection of a trenching ground, low-lying land which is subject to flooding or water-logging, or is not thoroughly drained during the rains is to be avoided. Well drained high lying land with a friable loamy soil is the best for the purpose. It should be selected to the leeward of the village or town, and should be screened from the public view. A piece of land of this kind well removed from dwelling-houses, but not too far from the village or town that is to be served should be selected. If too far distant a portion of the sewage will very likely never reach the trenching ground; the contents of some of the pails being emptied into some convenient ditch or spot removed from the public view. If it is impossible to secure a well raised piece of land then the site selected which is the best obtainable in the neighbourhood should be prepared by raising it above the level of the surrounding fields, and should be protected from their flood water and drainage. Ditches can be so constructed on each side of the trenching ground that drainage and flood water can be intercepted and diverted while the spoil earth from the ditches can be used for raising and levelling the trenching ground. If the earth obtained in this way is insufficient more earth can readily be obtained by excavating a tank close by. This tank, which should be within the limits of the trenching ground, will be useful for obtaining water for irrigation purposes during the dry season, as well as for supplying

water to the depot on the trenching ground for the cleansing and disinfection of the pails and carts. If the tank breeds mosquitoes the larvæ can easily be destroyed by pouring oil or paraffin on the water once every fortnight.

Preparation of the Ground.—The area of ground intended for trenching having been levelled and drained, it should be divided into twelve equal plots, these being intersected with metalled roads and pathways for the carts and coolies. Each plot should be of sufficient size to accommodate a month's sewage of the community to be provided for. The plots will necessarily vary in size according to the population of each community. The amount that each trench will take will vary according to the depth of sewage placed in each trench. This usually ranges from 2 to 6 inches according to the depth of the trench.

Kinds of Trenches and Area required.—Two kinds of trenches are generally employed. The first kind is shallow and is 2 feet wide and 9 inches deep, with a wall of earth 1 foot thick between the row of trenches. In this shallow trench 2 inches of night-soil is spread. The second kind is deeper, it is 2 feet wide and 12—18 inches deep with 1 foot of wall between each trench. At a maximum it receives 8 inches of night-soil.

The actual area required for trenching with the shallower system of trenches is 180 square feet per day per 1,000 persons. This area includes the trenches and the ground between the row of trenches. Multiplying this by the number of days in a year, the area required to allow of each day's area remaining fallow for one year is 65,700 square feet, which is equal to one and a half acres. The actual area required per 1,000 persons with the deeper trenches, which receive 8 inches of night-soil, would be a fourth of one and a half acres, or a little over one third of an acre.

These are liberal allowances of land. It depends on soil and climate as to the length of the rest. The twelve

months rest before retrenching is a maximum interval. In the Presidency Jail garden, where the trenching of the excreta of some 1,300 persons was carried on without offence year by year, the area was retrenched in half the time, *i.e.*, in about six months. The conditions, however, were particularly favourable. The larger area is always to be recommended for municipalities.

Filling of the Trenches.—The filling of the trenches is best carried out by the coolies emptying their pails into the trenches under supervision. This involves the least nuisance. A very offensive nuisance is produced by a cart being emptied into one end of a trench and the night-soil raked over the remainder of the trench, and this is a process which should not be adopted. In large municipalities overhead carriers should be provided on the trenching area, and the carts should be detached from their wheels, suspended on these carriers and run over the trenches and thus emptied in a systematic manner, or in smaller communities the carts should be emptied into pails in the depot of the trenching ground and the pails then carried by the coolies to the trenches.

In making the trenches it is preferable, if possible, to have one single line of trench or trenches to receive the whole of the excreta to be disposed of in one day. The plot for the month should then be large enough to contain thirty-one of these lines. In filling up the trench care should be taken that the earth covering it shall be laid on in a dome fashion, and not be merely level with the surface of the ground. The object of this is to permit a certain amount of sinkage of the covering of the trench, which always takes place, and which, if the covering was originally level with the ground would form in each trench a hollow or depression. Such hollows becoming filled with water during the rains will create a nuisance, and should therefore be prevented from forming. This is done by giving an arch shape to the covered trench so that when sinking takes place the covering does not sink below the level of the surrounding ground.

Cultivation of Trenching Ground.—This should always be carried out. Three months after trenching each plot should be deep-hoed, ploughed up, and then sown with rye grass, sugar cane or tobacco. After the first crop the plots are ready for vegetables of all kinds, which may be cultivated and sent to market without the slightest danger of being the carriers of disease through being grown on the trenching ground. In very dry climates and where dust storms prevail at certain seasons of the year, the trenching grounds should be well irrigated to prevent the soil from becoming dry and hard, and from particles of it, with what it contains, being raised by the winds and conveyed in the air towards any houses in the neighbourhood. If ordinary precautions are taken with respect to the site of a trenching ground, the levelling, draining, preparing, and laying out of that site, if, at the same time, the operations connected with the trenching are systematically carried out under intelligent supervision, which also secures irrigation of the ground when necessary; and provided thorough cleansing and disinfection of the carts and pails, and a cleanly state of the coolies are insisted on, there need be no fear, so far as the disposal of the sewage is concerned, that it will not be a success. On the contrary, if carried out on these lines there is no risk of the trenching ground being either a nuisance or, in the remotest degree, a danger. Trenching grounds have been blamed as the cause of typhoid fever among a community. There is no evidence for such blame being attached to a trenching ground, unless it is in a situation in which it should not be, and the operations are mismanaged. Even under these circumstances, except when the trenching grounds are in close proximity to the dwelling houses, and the latter are exposed to currents of wind from the trenching ground, it is difficult to separate the part played by filthy carts and pails which have not been cleansed and disinfected at the trenching ground. Certainly when the trenching ground is well removed from habitations, the condition of the carts,

pails, and latrines require to be first looked into, if any suspicion arises that the prevalence of typhoid may be due to the system of trenching. Of course in every known case of infectious disease in a household, specially marked pails should be provided for the house, and particular care should be taken in handling and cleansing them.

Allahabad System of Trenching.—The Allahabad system of trenching has been recently introduced into a number of military stations in India. It consists in removing 3 inches of the top surface of soil, thereby making a shallow trench, 16 feet long and 5 feet wide, and then loosening and pulverizing the soil in this shallow trench to a depth of 9 inches. The night-soil contained in a cart holding 60 gallons of excreta and slop water is emptied into this trench, with the result that the liquid which makes up about two-thirds of the contents of the cart sinks into the loosened subsoil, and the remainder, the solid matter, is carefully raked over the surface of the trench, forming a layer about one eighth of an inch thick. Another trench of similar size and kind is made adjoining and parallel to this, and treated in the same way, the 3 inches of soil taken from this trench being used to cover the night-soil in the first trench. These shallow trenches should be put at once under cultivation with grass and millet, which should be done without ploughing the ground. The usual arrangement is to sow sorghum and then lightly cover with earth, or sow both sorghum and grass. When the millet reaches the height of 4 feet, the grass has usually attained a height of about 1 foot, and both should then be cut. Six crops can in this way be obtained in the year, the last three being grass only. For this method of dealing with night-soil, sufficient land is required to prevent trenching over the same ground more frequently than once in four or five years. Where $1\frac{1}{2}$ acres per 1,000 persons would be required in one of the systems described, four or five times that area would be necessary for the

Allahabad system. The main objection to this system is the large number of flies which the operations seem to favor. Lieut.-Colonel R. Caldwell,[1] R.A.M.C., explains their presence by the hatching out of the flies from the larvæ in the soil, and their escape to the surfaces. Soil taken from the trenches treated with excreta and arranged in a box so as to form an exact imitation of a shallow trench, and then kept in the sun properly covered over with muslin, gave forth in a week's time a swarm of flies which were retained by the muslin cover. The presence of flies at certain seasons may, however, be of no great importance, if the trenching ground is well removed from dwelling houses. In this case the shallow trenches have been found to be a success, provided the locality is one not visited by dust storms.

No one familiar with the condition of military latrines in India will doubt the correctness of Colonel Caldwell's view that the ova of the flies which hatch in the trenching grounds are deposited in the latrines. Flies are more or less a pest of such latrines, being favoured in their development by the unclean, insanitary, and badly managed dry earth system which is so conspicuous a feature and a failure in so many of the latrines in military stations in India.

In reference to the disposal of excreta in a trenching ground, the main points connected with it may be summed up as follows: In the case of villages and small towns, when the excreta are taken by cart or pail to the trenching ground, whether from the cesspool where it has undergone bacterial change or from the pail where the excreta are fresh, the quickest and most satisfactory disposal is burial in shallow trenches regularly arranged and the cultivation of the soil. Trenches of 2 feet are too deep, because deep ploughing of the land is necessitated before the full benefits are derived from the system, and

---

[1] "Military Hygiene," by Robert Caldwell, F.R.C.S., D.P.H., Lieut.-Col., R.A.M.C., 1905.

the manure is brought in contact with the plants. Certain difficulties, however, arise in connection with this system in very dry and very wet countries. In a dry country it may be unsatisfactory unless it is conjoined with some system of irrigation which shall give moisture to the land. This can, as a rule, easily be obtained from wells or tanks on the trenching ground area. In a dusty country the burial during the dust-storm season should be deeper than the ordinary 9 inches, trenches 18 inches in depth being preferable, and the ploughing done when the season is over; or the excreta may be poured into a cesspool, properly protected on the trenching ground, and used for irrigation later on. In wet countries there may be a season of the year when, owing to much rain during the rainy season, trenching is accomplished with very great difficulty. Under these circumstances many of the difficulties connected with trenching might readily be overcome if there were in different parts of the trenching ground raised cesspools into which the sewage could be discharged until the land could receive it either for irrigation or direct trenching. The system may appear to be crude, but it overcomes certain difficulties, and has the merit of not being injurious to health ; and it is the prevention of the spread of disease and of the pollution of streams which has to be provided against.

In all trenching grounds where carts and pails may be taken with excreta in them, there should be arrangements for cleansing and disinfecting these appliances. It is to the absence of these arrangements and want of care in cleansing and disinfection of the utensils employed that any dangers that may arise from a trenching ground may be mainly attributed. I have never been able to trace disease to a properly conducted trenching ground. Swarms of flies over, or at any part of, a trenching ground indicate that it is not being properly managed.

Trenching in cocoanut plantations is also another method of disposal of the excreta. Trenches are con-

structed round the trees and the night-soil then covered over. This is a very safe and effective method of disposal.

It is often useful to combine with the trenching ground a septic tank with or without filters. In these cases some further dilution of the sewage brought by the carts is generally required, water for which can readily be obtained from a tank in the area included in the trenching grounds. The contents of the carts are then emptied into a subsidiary reservoir (fig. 57) which allows of an easy flow into the septic tank without disturbing the film that forms on the surface of the liquid in the septic tank, or interfering with the steady liquefying process going on there. The outflow from the septic tank should then be oxidized by passing in a thin stream over a weir, and afterwards purified by filtration. The effluent of the filters may be finally conveyed in furrows over a portion of cultivated and under-drained land.

When the excreta is thus dealt with, Mr. Silk, in some interesting experiments in Calcutta, demonstrated that a septic tank would hydrolyze in six or eight days the excreta of a native of India diluted only with 1 gallon per head of water in excess of the customary ablution water.

The tank on a trenching ground should be divided by several baffling walls to add to the area of the contact surfaces, and to impede the flow of the sewage, and it should be of sufficient capacity to retain the day's quantity of sewage for one week instead of for twelve or twenty-four hours.

The septic tank alone is not sufficient for the purification of the sewage. It reduces the solids and albuminoid ammonia, and prepares the sewage for filtration, but further than this it does not go. A warning of this kind is needed, because more than once I have seen installations of septic tanks alone and the effluent discharged into a stream, surprise being expressed that the results were so unsatisfactory. The exposure of sewage in a septic tank to the action of anaerobic organisms is only

SECTION ON AB

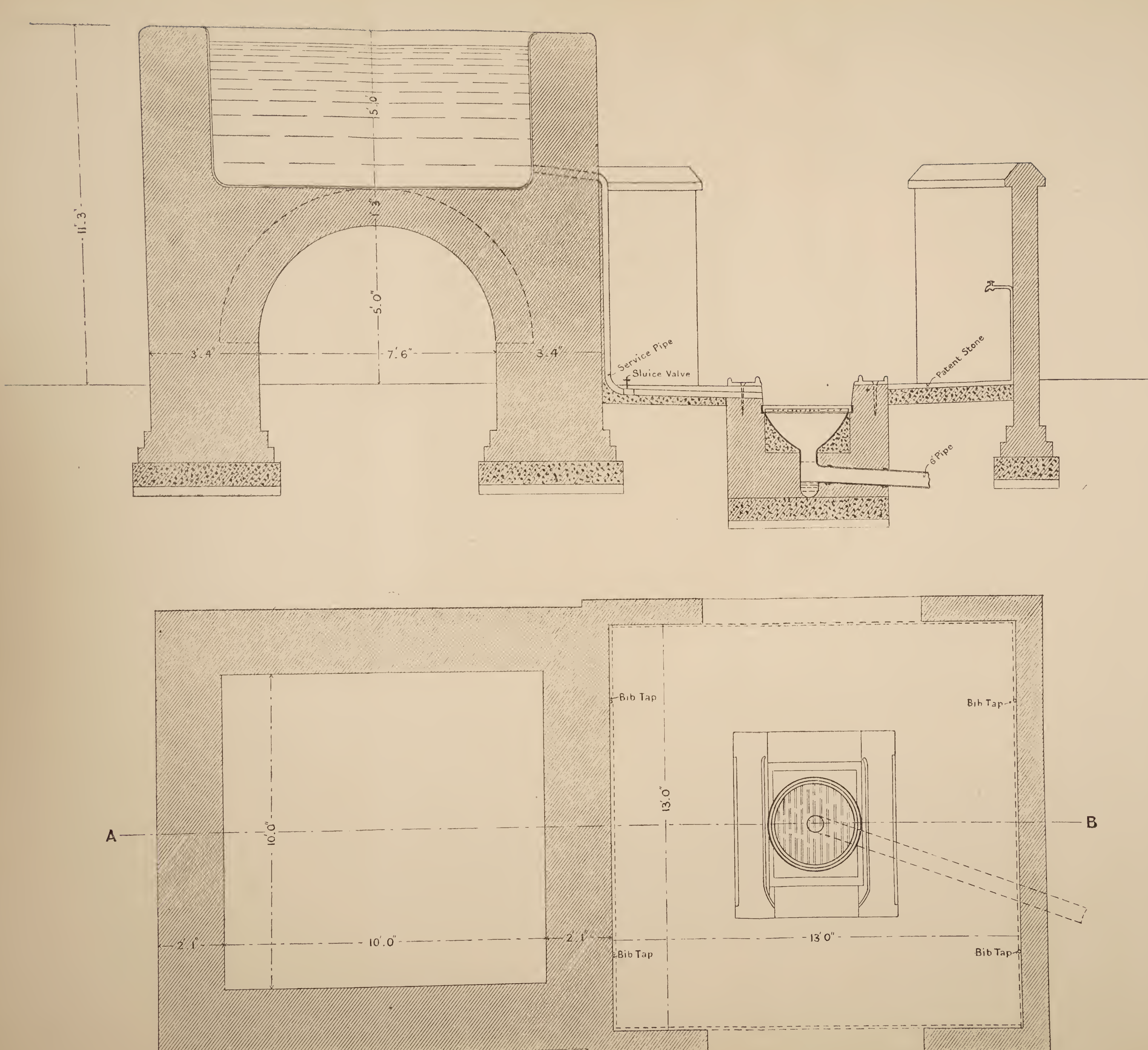


FIG. 57.—Calcutta Night-soil Depot with Reservoir.

Face p. 236.

GROUND PLAN

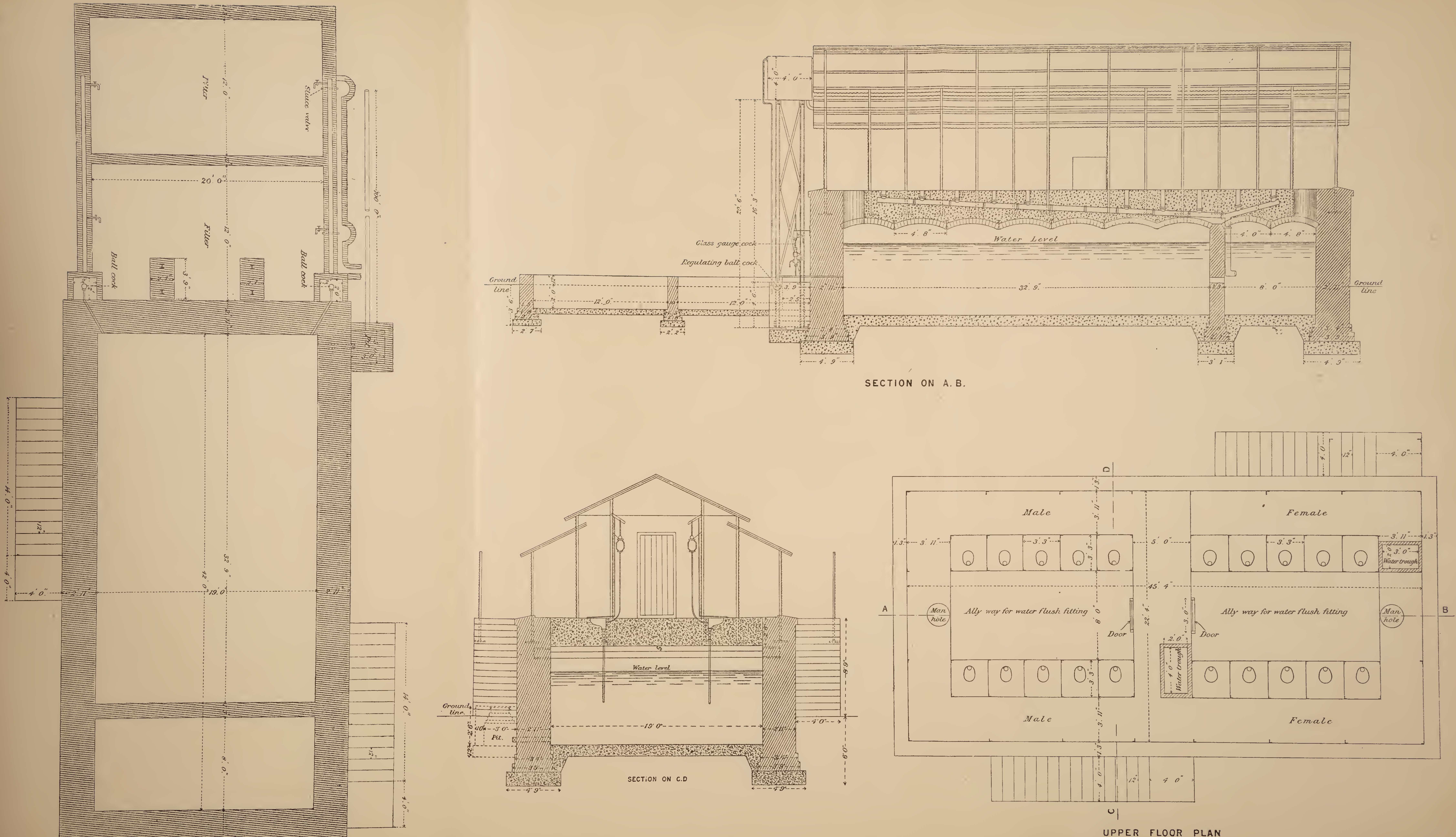


FIG. 58.—Plan of Septic Tank Latrine.

Face p. 236.

a preliminary stage to be followed by its subjection to the aerobic organisms during the process of filtration either through land or through artificial filters, or sometimes through both. Sometimes in unsewered localities, in the case of jails or other institutions where large latrine accommodation has to be provided, and where a supply of water is obtainable, a series of latrines with water fittings are constructed over reservoirs which act as septic tanks, and the outflow of which, after aeration, passes through filters for the purpose of purification. The effluent of the filters is then sometimes further subjected to land filtration or sometimes discharged direct from the artificial filters into a stream.

Fig. 58 shows a latrine constructed over a septic tank with filtering arrangements attached.

The modification of the septic tank system applied to latrines in the Tropics, and to trenching grounds or sewage farms is a more or less approach of eastern and western methods. It has been the custom for centuries for every Chinese farm house to have on the premises a number of covered vats which contain fæces and urine, either bought at the market or collected by the farmer's servants from the nearest town. The manure thus kept is generally retained in the vats for a period of two months before it is considered to be ripe for the fields. This custom, however, is not strictly adhered to, for fresh excreta are not infrequently added to the old.

The Chinese, especially of Southern China, are probably the most careful of all nations in the collection, removal and disposal of excreta, while they are perhaps the most careless in the removal and disposal of garbage and sulliage water. Their villages and towns, owing to the garbage lying in the streets and the sulliage water soaking into the soil or stagnating in the drains, are, speaking generally, the most filthy and most offensive smelling that can be met with. The solicitude displayed in the collection, removal, and disposal of the excreta is for agricultural purposes only. The manurial value

of the excreta is to such an extent appreciated that the passer-by is deemed to confer a favour by urinating in the receptacle provided near the shop or dwelling for that purpose. To own a public latrine in China is almost as lucrative a business as to own a pawnshop. Nothing under such a *régime* is wasted. In the villages, as stated, the latrines are openings immediately over large cemented cesspools, the contents of which to all appearances undergo certain bacterial changes similar to those in the recently introduced septic tank in England, for when emptied and discharged on to the adjacent fields or into boats there is no deposit, but the whole seems to be in a liquid state. The boats convey the sewage to the farmers, who store it in similar cesspits and apply it to the land. So expert are the purchasers of the manure as to its grades of value after admixture with urine or water that they are able to at once adjudge its worth in the market. It is seldom that fresh excreta are used. The market gardener has a cesspit in his garden into which fresh urine and fæces are daily poured. He stirs this up with the old and ladles out a small quantity each time he wishes to manure his plants (fig. 31, p. 179). For manuring the mulberry trees in connexion with the silkworm industry the solid excreta are alone used, but not in the fresh state. It is put into a pit and allowed to ferment for some months before being used.

Another mode of disposal essentially Chinese is that of using the solid excreta for maggot breeding with the object of using the washed maggots for feeding ducks. The process consists in pouring the night-soil minus the urine into shallow concrete pits 9 inches deep and 5 feet square, fresh material being added until the maggots appear in large numbers. In about eight days the pit is one mass of moving maggots living on the night soil. From then until the fifteenth day the Chinaman is busy taking out the maggots, washing, sorting, and packing them in tins, when they are ready to be

taken to the duck farms as food for the ducks. By this time the pit has had all its night soil consumed.

The objections to this mode of disposal near towns or villages are the offensive smells which arise from the places in which it is conducted and which travel a considerable distance, and the swarms of flies which are to be found on and near the night-soil pits before the appearance of the maggots and which may infect food in huts or houses close by.

Poudrette.—Sometimes the excreta are converted into poudrette, which is sold to farmers for manure. The process usually consists first in fixing the volatile carbonate of ammonia resulting from fermentation of the urea into a salt which will not evaporate with the water and then desiccating the sewage by evaporation. Sulphate of lime is frequently used as the fixing agent. In exceptionally hot and dry localities the drying can be effected in numerous shallow pans, the sun and air being the natural agents employed for evaporation purposes. This method has proved successful for the treatment of the Cairo night-soil, the poudrette being bought by the farmers. But where rain is heavy and frequent this method is impossible, and it is usually found that the cost of artificial evaporation is so great that the process entails considerable loss. It was tried on a fairly large scale at Singapore with modern plant, but proved to be a failure on account of the small demand for the poudrette and the high cost of its production. In the larger schemes sulphuric acid is generally added to the sewage, which decomposes the chloride of sodium in the sewage, forms sulphate of soda and the chlorine liberated in the process fixes the ammonia. About 8 gallons of sulphuric acid are added to 2 tons of sewage. The evaporation of the mixture in steam jacketted agitators necessitates the passing of the vapour through cremators having a temperature of between 1,500° and 1,800° F. Two tons of excreta yield about 2 cwt. of poudrette.

In some places poudrette is manufactured by mixing

the excreta with fine ashes, carbonized rubbish, &c., and then drying by exposure to the sun or artificially.

In Poona, the street garbage is burnt, and the ashes are used for mixing with the excreta. Beds 18 feet square and 1 foot deep have a layer 1 inch deep spread at the bottom, the night-soil to the extent of 4 or 5 inches is poured on the ashes, and this again is covered with another inch of ashes. In the dry season these operations are carried out in the open air, and the mass is allowed to remain for twenty-four hours exposed to the sun. In the rains they are carried out in a shed, and the mass remains untouched for three days. After this the night-soil is well stirred and well mixed and then another layer of ashes 1 inch thick is put on, and the whole is then left to itself for three days in the dry season and eight days in the rains. In the dry season the mixture is next taken out of the beds, exposed on prepared ground to the sun for twenty-four hours and then stored for sale. In the rainy season, the drying has to be effected under cover and the whole operation may take a fortnight whereas in the hot and dry season it is completed and the manure is ready for use in four days. There is a certain amount of nuisance attached to this mode of disposal and it is inferior to trenching. On the other hand, if a more liberal allowance of ashes were used and there were a demand for the poudrette it is a process that can be carried out with advantage in a dry climate. It is unsuitable in equatorial regions, or where there is much rain.

The Removal of Slop Water.—The removal and disposal of slop water is difficult except in institutions and places under the full control of a superintendent. Then the sulliage water is usually put into pails or tubs, the contents of which are removed daily by special slop-carts to the trenching ground or some other suitable locality. More frequently it is thrown down outside the house, or into some surface drain close by (fig. 59), which, if an earth drain, allows it to soak into the soil during the dry

weather and to form a dirty, fermenting, and offensive puddle during the rainy weather.

The ordinary preparation of food, cleaning, washing, and bathing, which have to be carried on in every household, entail the production of a certain amount of slop or sulliage water which has to be got rid of. Wherever then no sewers exist it should be insisted that when a house or hut is built, the same care is taken to provide a suitable filter and trench for the safe and healthy disposal of slop water as it is to secure a latrine for the collection

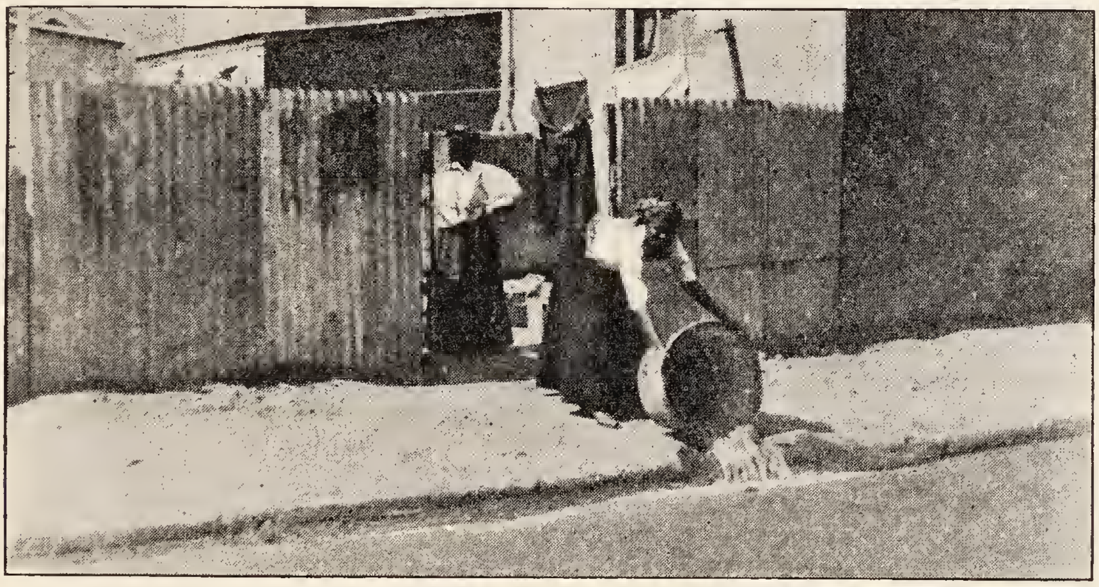


FIG. 59.—Washing-day. Laundry slops thrown on road-side.

of the excreta, and further, inasmuch as houses without privies must have them provided, a similar rule should apply to the provision of slop arrangements for houses without them.

When there are no slop-carts and no drains, the sulliage water may be purified by constructing a trench 18 inches deep and 2 feet wide, loosening the earth at the bottom of the trench, filling it with 4 inches of rough stone or broken metal, covering this with 6 inches of clean gravel, then 6 inches of sand, and on the top of all a single layer of stones or a perforated metal plate to keep the sand in position. By throwing the sulliage on to this filter the sulliage water will be purified and

will soak into the ground without creating a nuisance. When drains have been laid on the premises and there are no sewers the sulliage water can be conveyed by them to discharge on to the filter, which may be made wider and longer, but not deeper, according to the size of the house and the number of the inhabitants. The trench should be carefully guarded against the flow of flood water, which would at once destroy the value of the filter. In order that it should be so protected, the sides or banks of the trench should be raised 6 inches above the level of the surface of the ground.

Removal of Storm Water.—Storm water channels have to be provided. This may be done in sparsely inhabited localities by keeping open and in good order the natural waterways. In villages and small towns something more is required to convey the rain from the roofs and the premises of the huts and houses, and the general storm water of the village or town into the natural waterways outside the village and town.

For this purpose a system of surface drainage has to be devised, properly graded and made of concrete, cemented stone, or half pipes made of stoneware and laid in a cemented channel. This system of drainage should terminate in the natural waterways outside the village or town. It should receive also the sulliage water from each house, after this has passed through the filter drain where it is subjected to a certain amount of purification. These storm water drains should not pass close to wells, and should not receive sewage. Very often they do both and not only contaminate the wells that they are near by leakage or flooding, but also at times become a source of great nuisance owing to the smell of fæcal matter and urine. Whenever this is the case it is due to inefficient arrangements for the proper removal of excreta, and to absence of regular flushing of the surface drains. The chief points in such a surface water drainage system are that it shall be planned as carefully as a sewerage system and not in a haphazard manner as

convenience may at the time dictate, which is usually done, with the result that few of the parts fit into one another; that each of the premises shall discharge into the main channel and not pass through a neighbour's compound, and that the surface drains shall be so constructed as to carry off at least 80 per cent. of the rainfall. One inch of rain per hour per acre is equal to 3360 cubic feet of rain and the calculation is made from the general maximum rainfall in an hour. When the village or town in a low-lying district discharges its storm water into the sea or a tidal river, and the tide keeps back the storm water, the calculation is made on the consecutive maximum rainfall for the number of hours that the outfall is tide locked. In these instances sluices are always required at the outfall. From a health point of view these sluices are necessary, otherwise the tide runs up the drains, obstructs the drainage of the locality, not only near the sea but higher up, and causes the subsoil water to rise and produces a damp, marshy, and unhealthy condition.

Disposal of Dry Refuse.—The collection of garbage and its disposal are quite apart from the collection and disposal of sewage. Under garbage is included both domestic and trade refuse. Domestic refuse consists of all solid waste matter, other than excreta, coming from the household. In vegetable-eating populations it consists of the waste from sugar cane, maize, plantain, and other leaves, rice, remains of vegetables, fruits, fragments of fish, offal, and other kitchen refuse. Trade refuse consists chiefly of the refuse from stables, cow sheds, mills, manufactories, hotels and shops. The quantities of both domestic and trade refuse vary often according to the season of the year, and are gauged rather by experience than by definite rules such as apply to the removal of the excreta and liquid sewage. In Calcutta, with a population of about three-quarters of a million, from 1,000 to 1,500 tons of refuse were removed daily, for which there were nearly 900 carts, each of these

making three trips a day to the place where this huge mass of material was disposed of. The mode of disposal varies : cremation is undoubtedly the best, and the material is combustible, even though it does not contain the ashes and breeze of the domestic refuse of England. The kind of furnaces to burn this vegetable matter require to be constructed on a larger scale than those dealing with domestic refuse in England, and arrangements have to be made in the rainy seasons that the material shall have an opportunity of drying first of all in the furnace. With this proviso there is no difficulty in burning the refuse even during the heaviest rains without the addition of coal or at least with a very small amount. The unconsumed smoke and gases from the furnace require to be passed through a fume cremator in order that they may be broken up by an intense heat and rendered inodorous. The clinkers or ashes formed by the burning of the refuse in the furnace are found useful for road-making or for the preparation of cement. In England the heat derived from the burning of garbage has been utilized for heating water for baths and wash-houses, the generation of electricity, &c. When the refuse is brought to the incinerator it should, if possible, be immediately dumped into the furnace. If this cannot be done, a less sanitary method of disposal is that in which the garbage is used for raising the level of low-lying land. For this not to be injurious to health certain conditions are necessary; the land on which the refuse is deposited must be well removed from the town or village, the low land must be dry and not subject to flooding, and if there is flood water it must be carefully drained away and arrangements made by bunds (embankments) or other contrivances to keep it out. If these conditions of situation and dryness can be secured, then the garbage may be deposited on the low land to the depth of 2 feet, covered with a little dry earth and then cultivated; sugar cane, Indian corn and other plants being grown. By disposing of the refuse in this way,

a mould is formed on which rich crops can be grown. This land, after a time, can be raised another 2 feet, and dealt with in a similar fashion until the required level is obtained. As this made-up garden becomes larger in size, great care must be taken that the area it covers is properly drained and cultivated. The land so made is not fit for other than garden purposes. It is because these conditions are not rigorously attended to that the disposal of garbage in tropical countries becomes a source of serious nuisance and ill-health. In Bombay, for instance, the flats or low-lying ground within the city were formerly reclaimed by casting the garbage on to them and dumping it down irrespective of the marshiness and want of drainage, and the result was most deleterious to the public health. Similarly, in Calcutta at one time, the garbage was dumped into the salt lakes at the east of the city without any attempt to shut off the part that was being reclaimed and to drain it. The consequence was an area infested with flies and every foul eating thing, and a stench which was at times conveyed for miles, rendering the atmosphere perfectly putrid.

Fermentation and putrefaction proceed on a large scale in tanks or ponds filled up with refuse, even when covered over with 3 feet of earth. No amount of earth prevents the fermentation in presence of moisture. The Calcutta ponds have always been a source of cholera, and to abolish them has always been an important sanitary work. At one time it was thought that this could readily by done by throwing into them the garbage of the city. The nuisance this process created led the authorities to make certain rules as to emptying the pond first and then covering the garbage thrown in with 3 feet of dry earth. This system is now abandoned. It was a source of great nuisance and ill-health to the neighbourhood, not only during the process but long after the tank had been filled up. Some ponds in the Zoological Gardens were filled up with refuse in this

way and covered over with 3 feet of earth, but during and after the process many of the animals living near the ponds died, while numbers got into a state of ill-health. The putrefaction and fermentation with the formation of gases which go on under the ground when a tank has been filled up in this manner and then covered over, and the distance such gases may travel, are illustrated by the following incident which occurred under my own observation.

A large tank was filled up with garbage and covered over with 3 feet of earth. About four months after, near the end of the rainy season, an old woman living about 150 feet from the banks of the tank, lit her kitchen fire one morning. The fire-place consists of a mud arrangement on the floor and the fuel used is cow dung mixed with coal dust. To her astonishment, when the fuel that she had put on the fire was consumed, the fire continued to burn. With the strange continuous flame she was enabled to cook her food each day for more than a fortnight without being at the expense of buying fuel. She kept the matter secret for some days, but at last told her neighbours, who, being invited, came to see the wonderful light. Her visitors, however, became so numerous that it occurred to the old woman she might make some money from the exhibition. Accordingly, she began to charge a pice a head and in one day made as much as four rupees. The flame issuing from the ground was believed to be the tongue and breath of the devil. Unfortunately for the woman's good luck an inquisitive visitor dug several holes around the hut to ascertain where the flame came from. The gas, which had found in the woman's fire-place a convenient opening for escape, had now other openings to pass through, and consequently the flame was extinguished and, on re-lighting only burned fitfully and ultimately disappeared. The marsh gas generated on the decomposing garbage in the filled up tank, had travelled underground as far as the hut, and finding an opening under the fire-place, gave rise to

the phenomenon. If other openings had not been made the flame would probably have continued for a very long time. This formation of an inflammable gas by fermentation is similar to that already referred to as being produced by the fermentation of sewage in a septic tank. Only in the one case it is due to the decomposition of vegetable matter chiefly, while in the other it is that of animal and vegetable matter. In both conditions the supply of air is very limited. Decomposition in dumping grounds or tanks of great depths filled up with refuse will go on for years. I have seen the newly turned up soil of a tank filled up thirty years before to be quite offensive and putrid. Houses or huts built on or near soil of this kind are unhealthy.

Tanks should always be filled up with clean soil, or with the cinders and clinkers obtained from an incinerator. In filling them up they should be first emptied, and as they are likely to receive water when filled up, drains should be laid at a depth of 5 feet, the outlet of which should discharge into the nearest water course or surface water drain, so as to drain off any subsoil water settling in the tank, that may have risen to that height. This is generally done by making a wall round the tank of coarse rubble, or road metal, laying in this stoneware drains with open joints and connecting them as mentioned.

The removal of broken bottles is an important part in the conservancy of a district. The garbage will putrify and become a nuisance and will attract flies, but broken crockery and utensils lying about hold water during the rains, which will, if not emptied, become breeding places for the larvæ of mosquitoes. These things are therefore to be removed regularly and systematically. Those that can be destroyed by burning should be so treated, and those that cannot be burnt should be buried or used to help in filling up low lying land, care being taken that they are always covered with earth, otherwise the procedure would be only setting up another breeding-place for mosquitoes.

CHAPTER X.

REMOVAL AND DISPOSAL OF SEWAGE BY WATER CARRIAGE SYSTEM.

Separate Systems of Drainage and Sewerage best Adapted for the Tropics.—In large towns provided with drains and sewers, the system of underground removal and disposal of the sewage, solid and liquid, conforms closely to that adopted generally in Europe. There are, however, certain important points of difference. First, the system which is best adapted for the Tropics is the separate system, that is, the storm water should, in all instances, be separated from the sewage, the storm water going direct to the river, the sewage to the land to be purified before admission to the river. The objections to a combined system are that the rains are generally so heavy that if the combined system is introduced, and an attempt is made to construct the sewers of sufficient dimensions to carry off the storm water in an efficient manner, they require to be made so large that instead of sewers they are small covered canals, the construction of which is very costly. Such sewers have the disadvantage in summer, when there is only a small quantity of sewage flowing in them, of becoming huge reservoirs of sewer gas, which discharge into the atmosphere most offensive odours. It is impossible for sewers of this kind to be self-cleansing; during the dry season they become charged with deposit and highly offensive. Further, a combined system renders efficient sewerage during the rains an impossibility. It is essential, therefore, unless under very excep-

tional circumstances of small rainfall, that no attempt be made to dispose of the tropical rains by underground sewers which carry sewage, but that separate storm water channels be provided and separate sewers. A compromise is sometimes made by which the sewers are made larger than is absolutely required for the sewage, and the first flow of the storm water is admitted into the sewers, after which, by mechanical contrivance, no more is admitted, but the rest is diverted into the storm water channels. The object of this is to take to the sewers the foul washings from the roads, which would otherwise be taken into the storm water channels.

Sometimes the drains and sewers are only used to convey from the privy the urine and ablution water, but as these are as much sewage as is the solid matter there is no advantage in this separation. It may, however, happen that a population has to be dealt with who will not use water-closets, or who will ill use them; and then the dry conservancy system has to be used for the fæces, while the urine and privy washings pass into the drains. In these cases often the privy floor slopes, the solids being retained and the liquids flowing into the drains. When water-closets can be used they should be introduced, but they should in the Tropics never be located in houses as in Europe. They ought, invariably, to be separated from the house. This should never be neglected, for water-closets in the house in the Tropics invariably cause ill-health, owing to the fact that in the rains no traps or ventilators yet devised prevent sewer gas at times getting into the house; and during the hot weather decomposition goes on so rapidly in the sewers that there is always danger of the escape of sewer gas into the house. With the proviso that the water-closet should be outside the house, it is undoubtedly the quickest method of getting rid of the sewage with the least nuisance.

When a latrine is required for each storey of the house, a separate tower for the latrines approached by verandahs

from the different storeys of the house is the best arrangement (fig. 60), not only should this arrangement be adhered to in private houses and hotels, but also in factories, warehouses, or other buildings where it is

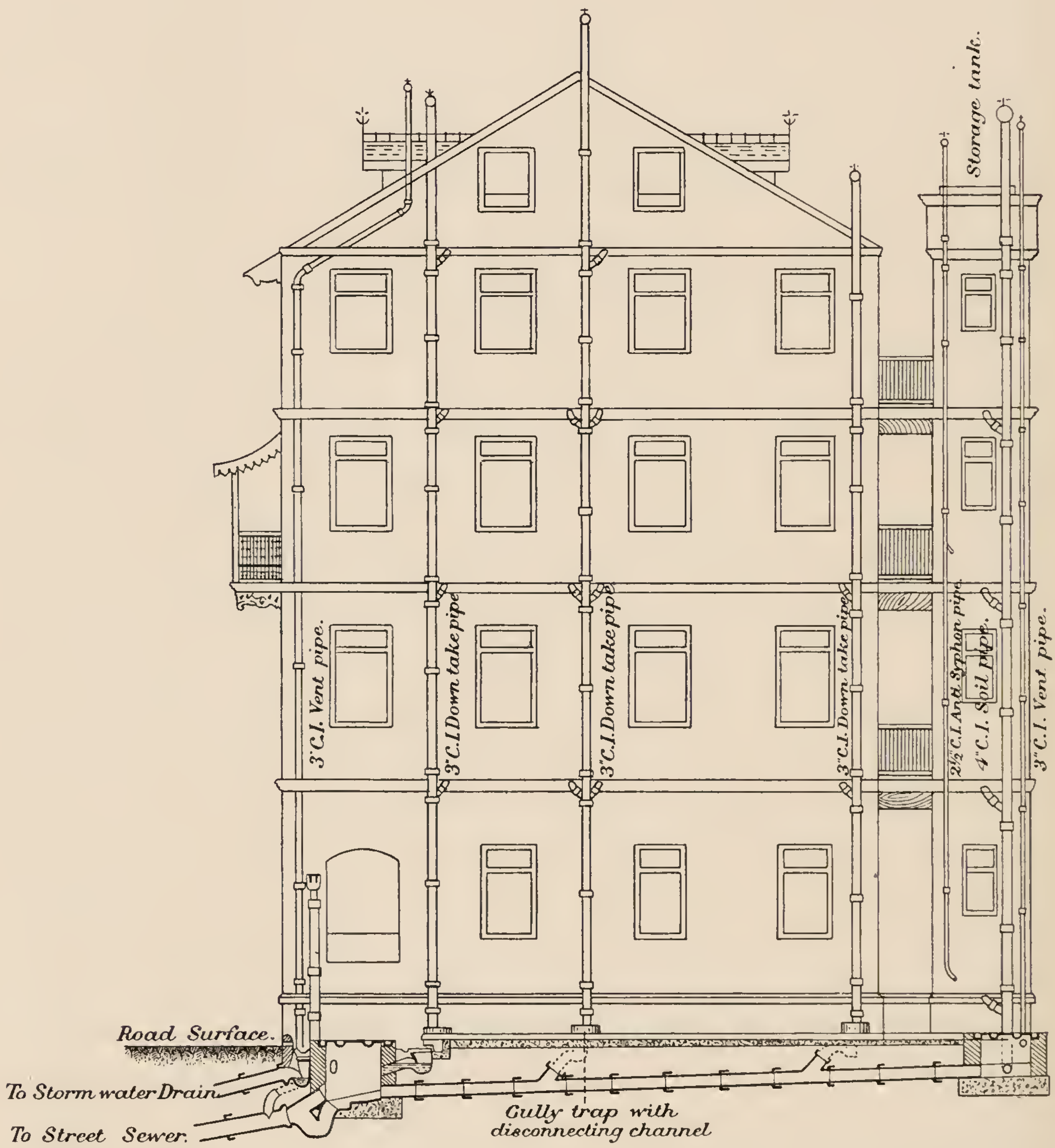


FIG. 60.—House with latrines arranged in separate tower approached by verandahs.

thought desirable to have closets or urinals for the upper storeys. This tower should always be at the side of the house, or so situated as not to interfere with ventilators at the back of the house.

There are few towns in the Tropics that possess a

water carriage system of sewage removal, and even those that do possess such a system seldom follow in its entirety a European model. For Europeans resident in the town, and for many of the better class natives, water-closets of European and native types are used, but for the vast majority of the population the system adopted is a sort of compromise between water carriage and manual removal, under any circumstance.

Special Water-Closet Platforms required.—The seat and flushing arrangements would be the same for Europeans as they are in England, but for natives the seat requires to be adapted to the squatting position, and the flushing arrangement must, as a rule, conform to their customs and habits. In large latrines used by all classes few will touch the handle of a water-closet in order to bring on the necessary flush after use, and recourse must usually be had to automatic means of securing the flush. Several methods have been adopted. One method is to effect it automatically by a self-acting syphon flush liberated at stated intervals, another is to prepare the flush by the weight of the user's body on the platform, which will be released immediately the weight is removed. A third is worked by a lever when the latrine door is opened and closed. The automatic flush wastes, as a rule, much water, and the other contrivances are apt to get out of order.

Not infrequently the water used in the house for bathing and domestic purposes can be conveyed to the closet and used for flushing purposes in a similar way to Duckett's system in England.

The difficulty which arises in most of the water-closet appliances and fittings is that they are adapted only to public latrines and urinals of large institutions and barracks, and to a minority of the houses connected with the sewers. For the remainder they are generally too advanced for the population that has to use them, and the water-closet has to be of the simplest kind flushed by the emptying of water down it, or by the utilization of

the bath-room and sulliage water, or in its place the ordinary pail has to be used as in localities without sewers. In the Tropics sewers are often only an indirect system of removing the sewage from the house, though a direct system of removing it from the town to the outfall.

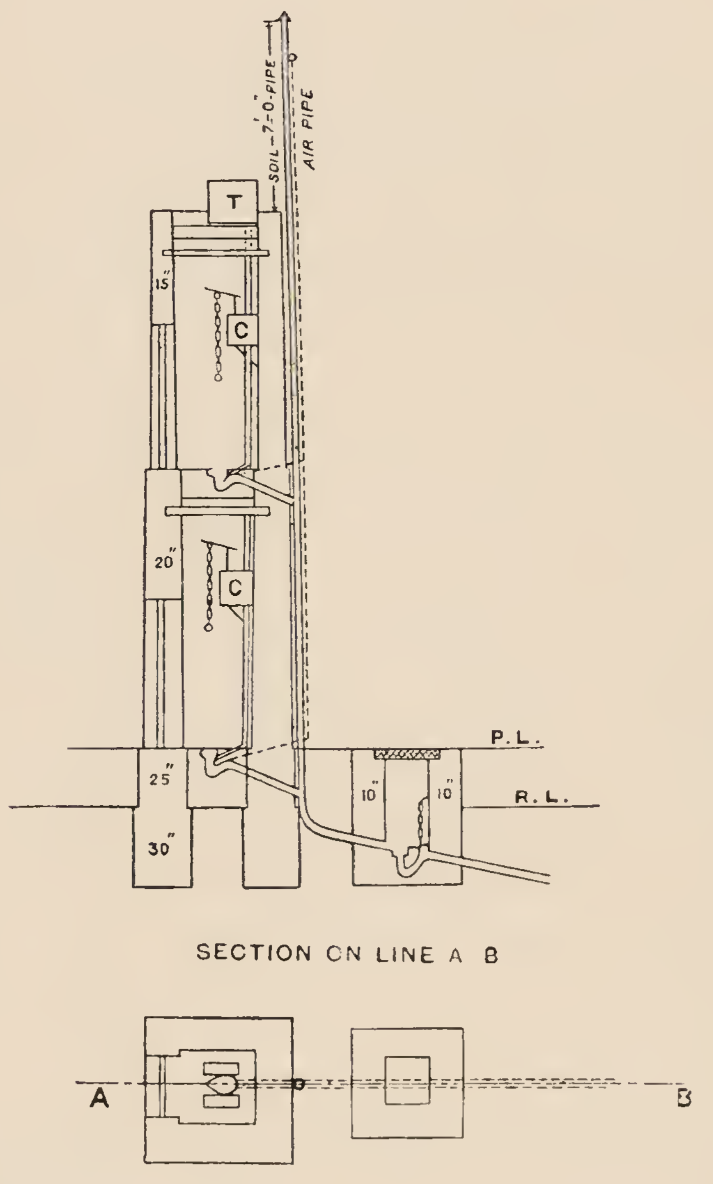


FIG. 61.—Connected latrine in Calcutta.

Improvement Effected in Old Shaft-Privies.—The upper-storied houses with their drop-latrines on each floor and shafts ending in a vault on the ground-floor containing one or more receptacles, have already been mentioned. These are the worst examples of a more common form of drop-privy (fig. 40, p. 208) existing in most Indian cities. Particularly bad in Calcutta, the whole building contain-

ing the shaft was gutted out and pipes were substituted as in fig. 61. Each latrine was provided with a separate soil-pipe which discharged over a basin in the floor of the chamber connected with the sewer, and in this chamber a flushing tank was placed with its discharge pipe leading into the basin in the floor. The flushing of the latrine and soil-pipe was generally effected by the mehtranee or mehter throwing down buckets of water into each latrine.

Mr. James, the Municipal Engineer for Bombay, devised, instead of the ordinary Indian privy in use in Bombay (fig. 39, p. 206), an intermediate privy (fig. 62) adapted to the high houses and sewerage system of that city. It consists of a 6-inch stoneware pipe which replaces the shaft and extends to the roof of the building, and there ventilated, a stoneware pan at the bottom of the shaft which is substituted for the ordinary receptacle and which is connected with the sewer, an automatic flushing tank fixed on the wall outside the vault, containing 20 to 30 gallons of water, according to the number of privy seats. The pipe of the flushing tank is connected with the soil-pan, and regularly flushes the contents of the pan into the sewer. Arrangements are made in the pan to intercept stones, tiles and rags, which are removed daily by the sweeper.

Neither of these is an ideal system, but either is a vast improvement on those replaced, and with regular attention and inspection on the part of the Health Department, is not a nuisance.

As time goes on there is a tendency to connect these privies directly with the sewer. If this cannot be done, arrangements similar to those in a European compound might be adopted, the one water-closet receiving the sewage from the house, with the ordinary arrangements, the receptacles under the latrine platforms being used for the excreta.

Latrine Arrangements in European and Native Houses.— The majority of native houses, though they may have

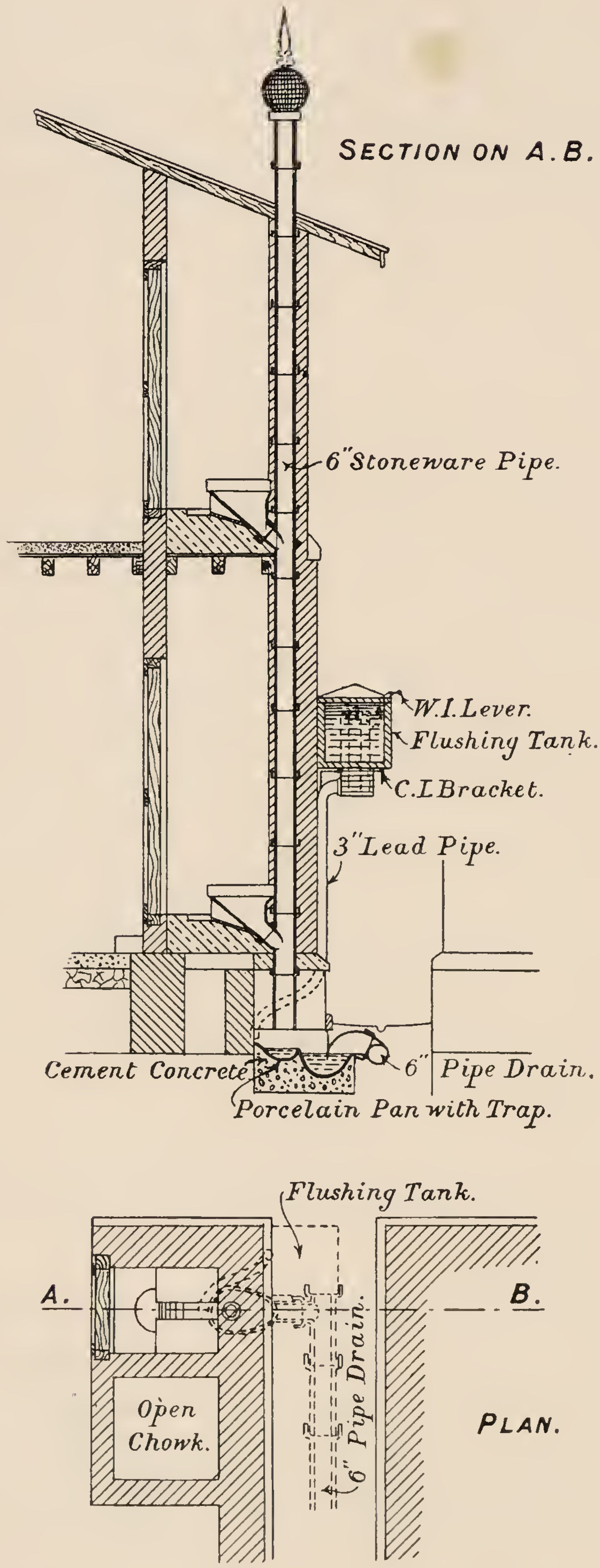


FIG. 62.—Intermediate Privy adapted to high houses and sewerage system of Bombay.

drainage to carry away sulliage water and urine, do not have their latrines connected directly with the drain or sewer. It is the exception for the excreta to be conveyed from the house direct into the drains and from these direct into the sewers, which carry it out of the town to the outfall. In European houses, as a rule, the bathroom contains a commode which, when used, is emptied, in the case of a sewered town such as Calcutta, into the servants' latrine, which forms one of the outhouses on the premises. This servants' latrine is a native water-closet; the drain from which is connected with the street sewer. By this arrangement there is only one water-closet on the premises, it can be kept under supervision, and if it gets out of order its situation precludes any danger to health. In native houses there are, as a rule, no water-closets; one or more privies with receptacles under the platform to receive the excreta being the usual arrangement. These receptacles or the excreta in them are removed by the mehter or scavenger to a special depot, which is the substitute for the servants' water-closet on the European premises, differing only in its size and in serving a number of houses in the district instead of one house. The depot communicates with the sewer and has emptied into it the excreta brought from the different houses.

Sewage Depots.—Arrangements are, or should be, provided in the depot for the cleansing of the utensils brought to it, and also for their thorough disinfection. The usual mistake in constructing these depots is to make them too large and to have too few of them. The result is that too much excreta is taken to each, and they become an offensive nuisance to the localty in which they are situated. If, on the other hand, they were smaller in capacity and more numerous, and properly conducted and supervised no nuisance need arise from them. These depots are adapted to large and small towns alike, to those that are elaborately sewered and to those whose sewerage consists only of a few pipes. As regards removal of excreta it may be

broadly stated that no town of over 10,000 or 15,000 inhabitants can deal satisfactorily with the removal of its excreta other than by a system of pipes. This need not involve an elaborate system of sewage, but it requires a supply of water.

In cantonments where a sufficiency of water is obtainable a system such as this can be applied to meet the requirements of the commode system of the European and the pails of the natives, while for the barracks in

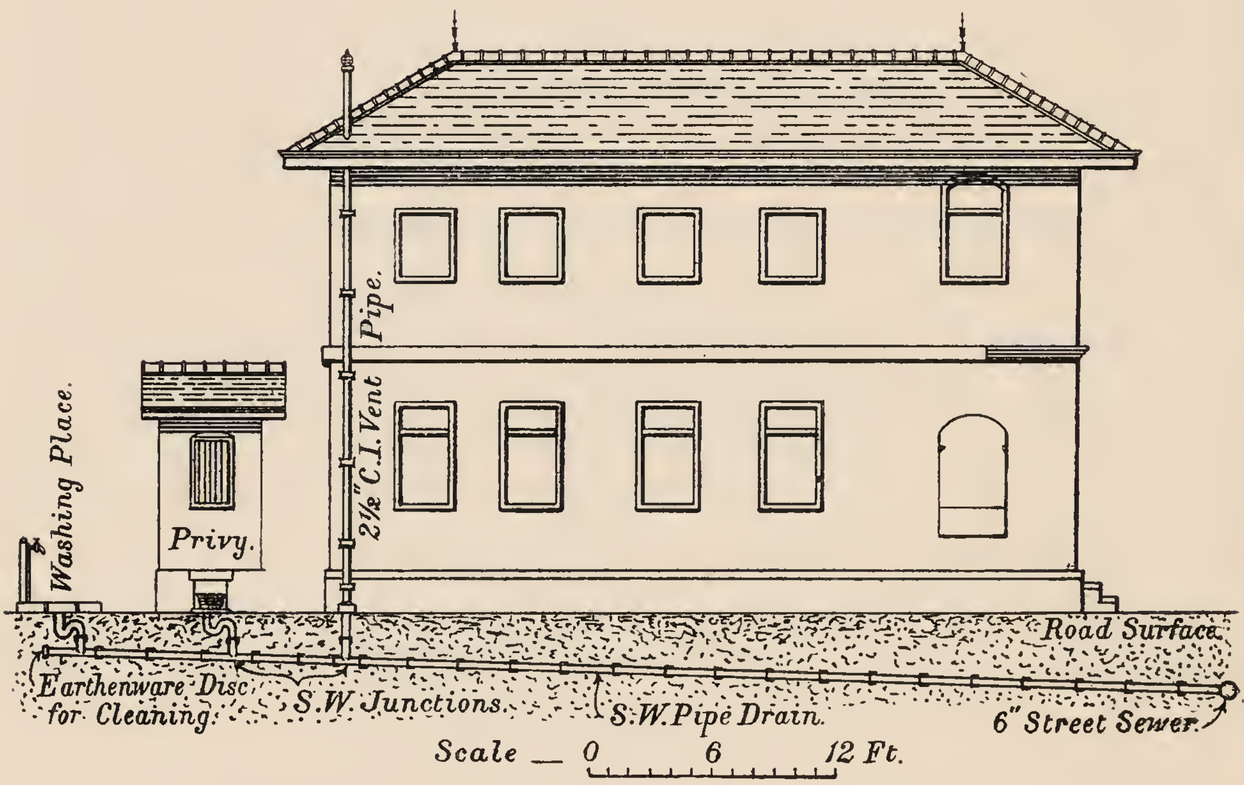


FIG. 63.—A Connected House Latrine, Calcutta.

which there is always a concentration of men, water-closet latrines adapted for natives and Europeans within easy access of each barracks might be substituted, thus obviating the creation of any nuisance or danger, as at present attached to the management and handling of a large number of pails used by large numbers of men.

Examples of Connected Latrine Arrangements.—For houses in which the latrines are connected directly with the sewerage system fig. 63 (designed by Mr. James, for Bombay), and fig. 64 (designed by Mr. Ault, for Rangoon), illustrate the usual arrangements. The latrines are out-

side the house. They, as well as the bathing and cooking offices, should be built with pucca or cement floors, and the drains therefrom led to public sewers laid in the

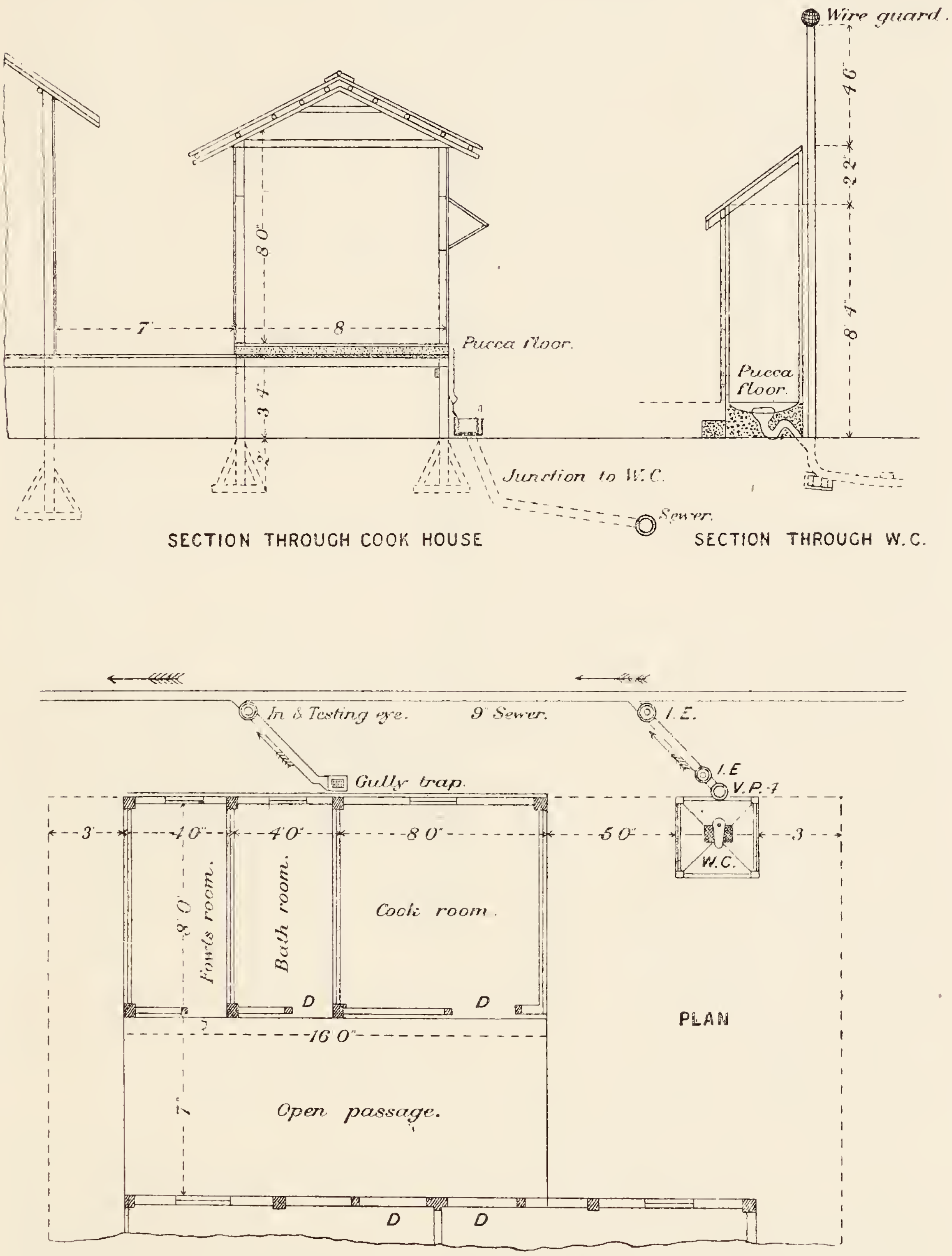


FIG. 64.—House Latrines arranged by Mr. Ault for Rangoon.

drainage spaces. In the Rangoon arrangements there is no direct water service to the premises, the water being carried by the householder from the street standposts

to the house. Fig. 65, shows the arrangements for a public latrine and urinal, such as is used in Calcutta.

Sewerage.—Wherever a sufficient fall exists gravitation sewers are as adaptable to the needs of the Tropics as to those of cold climates, and the same system can be introduced, always provided that it is a separate system. Arrangements must also be made for regular flushing, for cleansing, and for ventilation. The sewage should be carried to the outfall as quickly as possible in order that after its arrival there it shall be disposed of in as fresh a state as possible. There is no need to enter into details.

The Shone System.—The gravitation system is, however, not suitable for towns which possess very little fall, and this is the condition of most of the towns in the deltas of great rivers. In flat places, and those badly adapted for the introduction of gravitation sewers, a more suitable arrangement is that of the Shone Hydro-Pneumatic Ejector system. It consists of a central air-compressing station, at which compressed air is stored and distributed by wrought iron pipes to ejectors placed in chambers sunk under roads or streets or fields in different parts of the districts to be drained of their sewage discharges. The sewage is conducted to these district ejectors by ordinary gravitation pipes, and when they are thus filled the compressed air is automatically admitted and ejects the sewage through pipes leading from the ejectors to the outfall. Rangoon, Kurachi, and some parts of Bombay are thus successfully drained.

The system has also been established in the low lying part of Rio de Janeiro and other tropical towns.

The advantages of the Shone system are that :—

(1) By its adoption proper scientific gradients for drains and sewers can always be secured, however unfavourable the configuration of the habitable areas may be. This is a very great advantage, for it enables engineers to design and lay down self-cleansing drains and sewers anywhere and everywhere regardless of surface or physical condition adverse to natural gravitation.

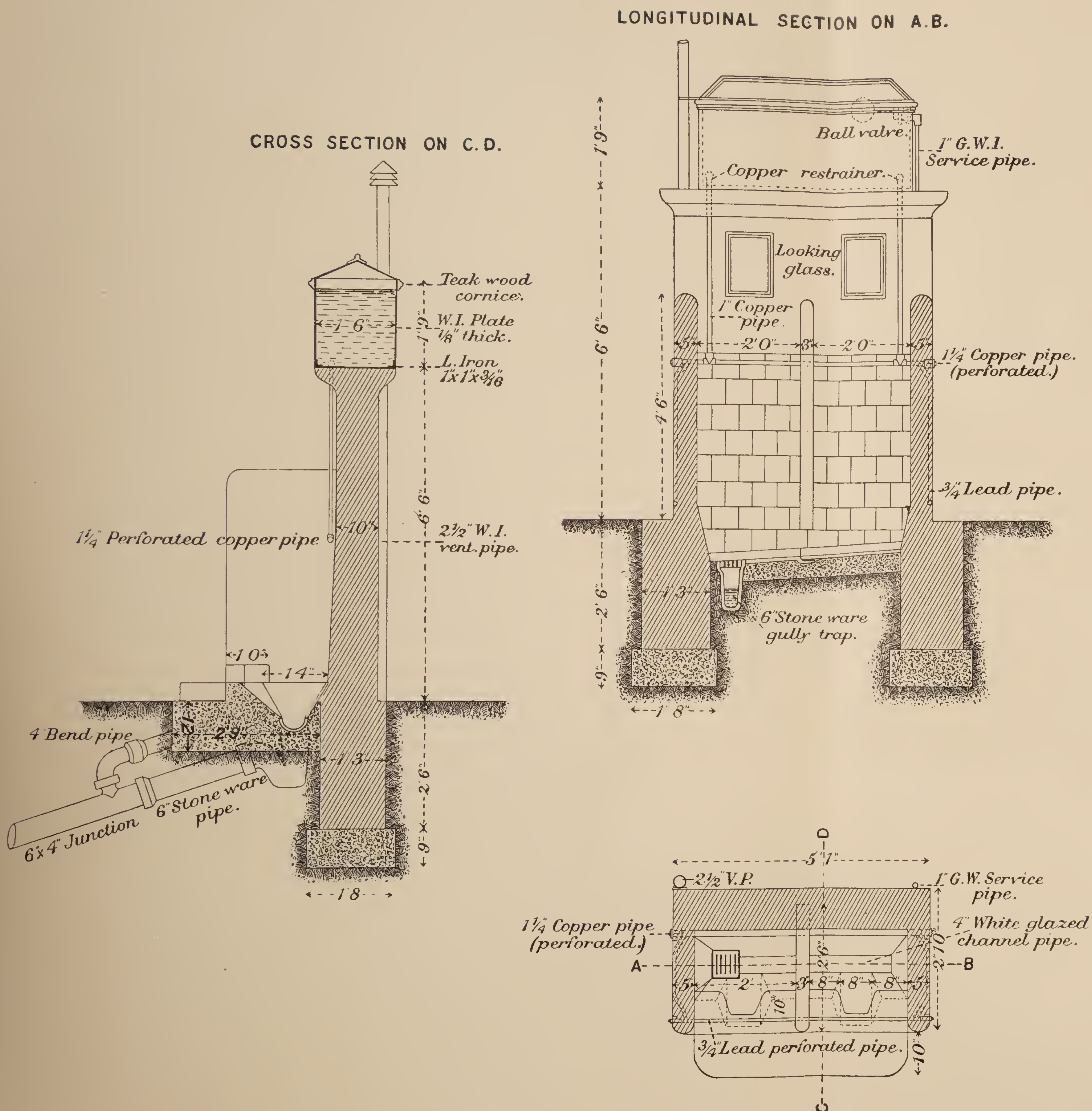


FIG. 65.—Public Latrine and Urinal, Calcutta.

Face p. 258.

In towns built as Singapore, on flat, low-lying lands, it is impossible either to design or construct water-carriage sewage drainage works which shall, after installation, be preserved permanently in a thoroughly sound and sanitary condition, without having recourse to mechanical contrivances which shall be equivalent in all essential respects to those which are now used in connection with the working of the Shone drainage and sewerage ventilation systems.

(2) It can be laid down in districts in sections, and a district or section once completed, can be set to work without waiting for the completion of other sections or districts. Each part of the town can thus be independently drained.

(3) Its power is derived from a single central station at which atmospheric air is compressed, and from which the compressed air is distributed to work the several district ejectors.

(4) The working of its sectional ejector stations requires very little attention as it is automatically performed by the compressed air supplied to them from the central power station.

(5) The ejectors in every district are underground, and cannot be interfered with except by the officers responsible for their working.

(6) The Shone ejectors being worked by compressed air are necessarily more sanitary in their operations than the ordinary steam power pumping stations, which have more or less large sump pits, in which volumes of sewage are stored, and where the deposition of sewage-sludge takes place, and where also extraneous material, such as rags, &c., accumulate before they are periodically removed.

Competent and trustworthy authorities have ascertained that the application of compressed air to the work of ejecting sewage on the Shone system for low lifts, up to from 25 to 30 feet, gives an efficiency of nearly 50 per cent. as proved from careful tests by Professor Unwin, whereas by the application of hydraulic power, pumping

sewage to the same heights, has only yielded, in carefully designed and worked installations, from 16 to 20 per cent. at most.

Fig. 66 illustrates in a simple manner the principles on which a district or town may be drained on the Shone

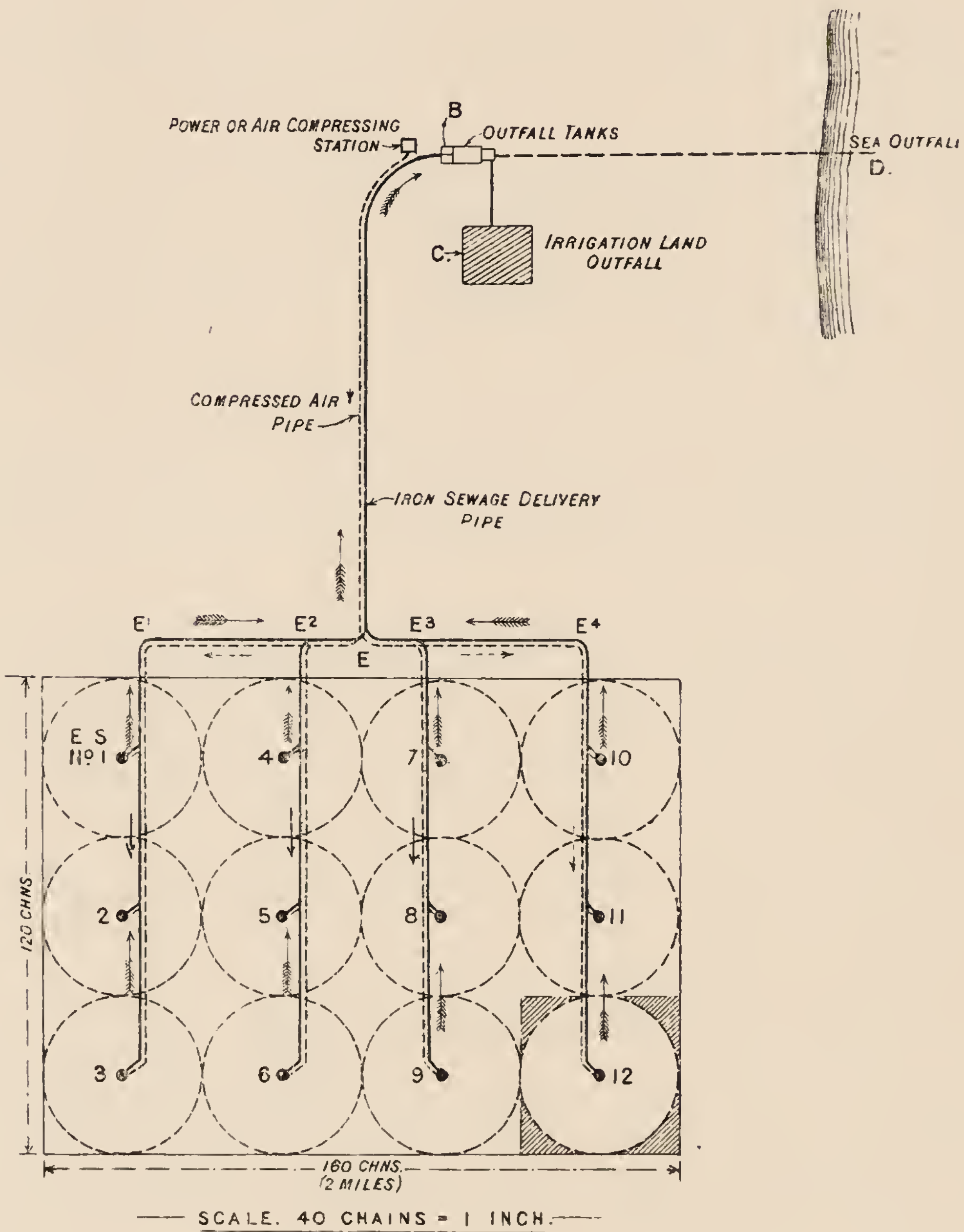


FIG. 66.—The Shone system.

system. In this diagram the ideal district or town consists of a plot of land 160 chains or 2 miles long, and 120 chains or $1\frac{1}{2}$ miles broad, containing 1,900 acres. It is divided into twelve drainage sections, in the centre of each of which is an ejector station. Each ejector station is fed by the sewage flowing down the gravitation sewers

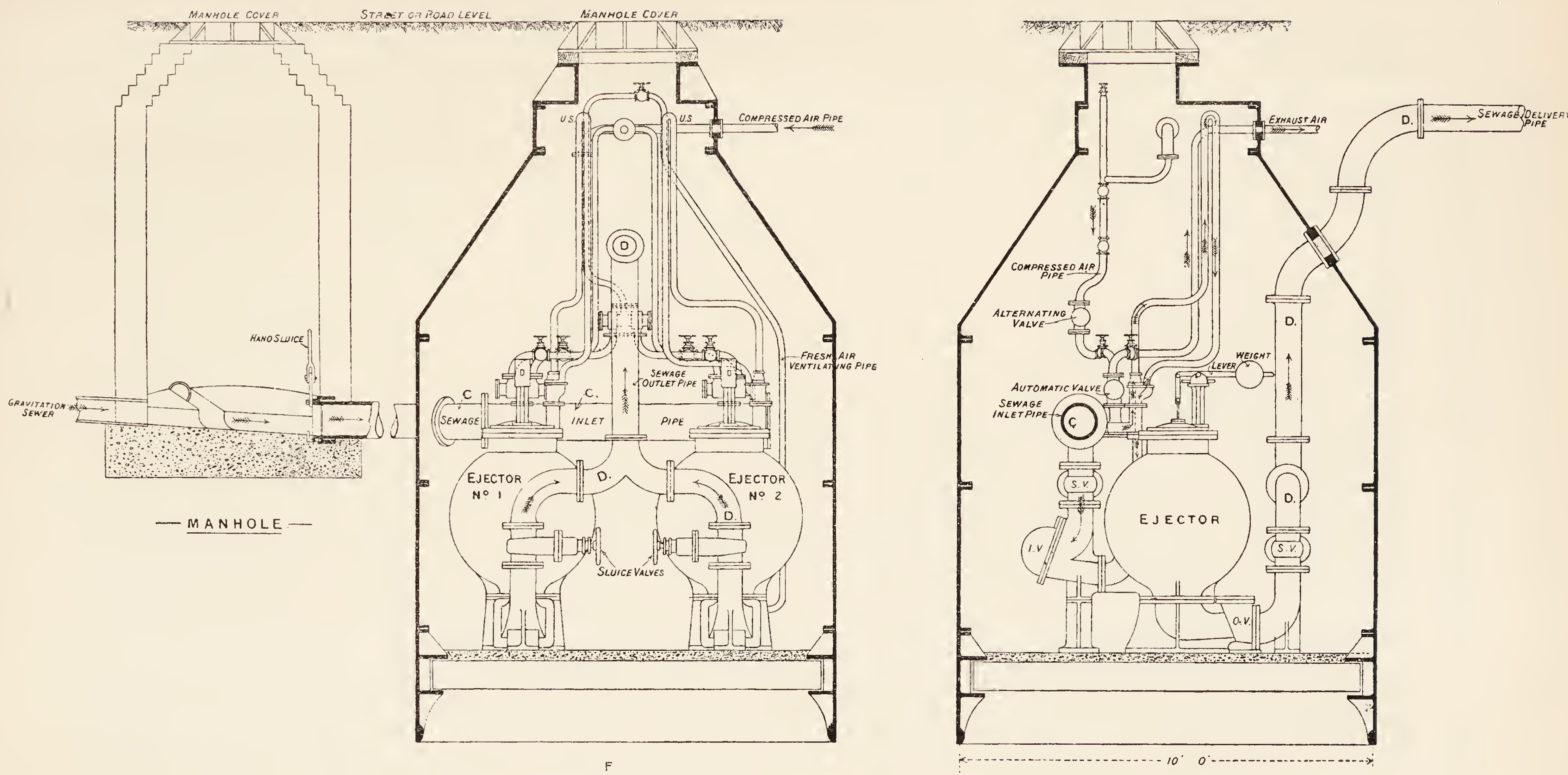


FIG. 67.—The Shone system.

within each section, which converge to a manhole which adjoins each ejector station.

Fig. 67 shows a specimen of a manhole built in brickwork, and F and G a specimen of an ejector station built in cast iron and containing ejectors in duplicate. This ejector station, if built in brickwork, would of course be as convenient for the reception of the ejectors as if it were built in iron. Brickwork suffices where the subsoil is dry, but where it is wet, iron is preferred generally speaking. In the drawings F shows the ejectors and their accessories *in situ* longitudinally, and G shows them transversly.

All things being equal, therefore, each of the twelve ejector stations ideally planned as per fig. 66, would receive and discharge the same volume of sewage per minute or per day, a condition of things, however, which would never occur in practice. From each of the ejectors the sewage is discharged, as already stated, automatically by compressed air into the main iron delivery pipe, which conveys it to the outfall tanks B. After treatment in the tanks, the sewage thus ejected from the ideal town producing it may be delivered by gravitation direct into the sea, say to the point D, or it may be conducted by gravitation direct on to the land to the point marked C for irrigation purposes ; or failing gravitation the sewage effluent from the tanks could be ejected to the point C, or to the sea at the point B.

If the water supply of this hypothetical town amounted to 30 gallons per head per day, and the drainage works were on the " separate " system, this volume would also represent the sewage discharged per head per day of the population.

The sanitary value of these ejectors is overlooked by those who advocate sewage pumping machinery which will give out the greatest efficiency in steam consumption. It is forgotten that the very highest possible duty which is attainable from pumping machinery, if that machinery is pumping sewage at the tail end of long lengths of ill-

ventilated outfall sewers of deposit, will have very little, if any effect in increasing the general sanitary efficiency of such sewers. It is more important to have high sanitary efficiencies from the working of drains and sewers than it is to have exceptionally high efficiencies from sewage pumping machinery. An efficiency of 50 per cent. from ejecting sewage direct by compressed air, over that of pumping it in the ordinary way by steam pumps really means, after all, a high efficiency for low lifts, and when in addition, the ejectors, unlike pumps, will take the raw crude sewage in an unscreened state, and eject it in that state automatically to its destination, as fast or as slow as it flows down the sewers to the various ejector stations; and since one power station suffices to operate as many as twenty-six ejector stations, as at Rangoon for instance, there can be no doubt that the Shone ejector system is superior in every respect to the ordinary sewage pumping methods.

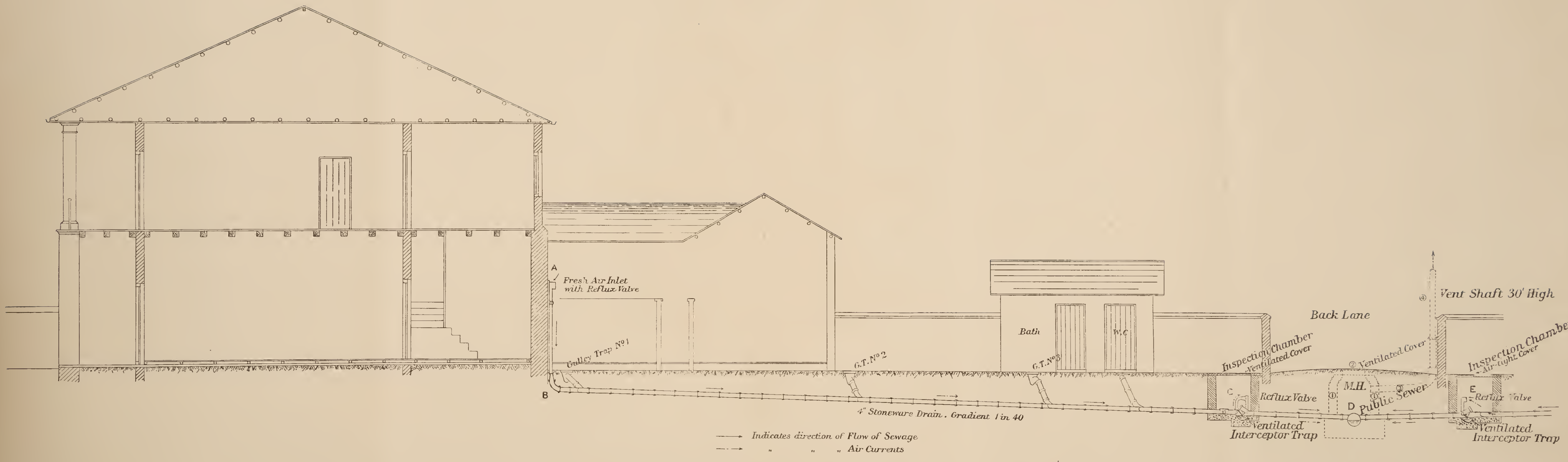
Ventilation by the Shone Hydro-mechanical System.—Fig. 68 shows the way in which the ventilation of drainage and sewerage works whether wholly or partially on the gravitation plan or otherwise can be effected on what is called the Shone Hydro-mechanical system. The drawing in this diagram shows in sectional elevation the kind of houses, &c., which are built on either side of such streets as are to be found in oriental towns, as in Singapore for example.

The Shone plan of removing the sewage of houses and other buildings connected with their curtilages, is also illustrated in fig. 68, which likewise shows how the main drains of such buildings would be ventilated.

The air used to ventilate the main drain and the public sewer would enter the perpendicular pipe at the point marked A, and would proceed down that pipe to a point marked B, and thence down the drain (with the sewage) to the interceptor fixed in the inspection chamber marked C. On its arrival at the interceptor its course to the sewer will be in the direction indicated by the

arrows. At the top of the small pipe which carries the air from the house-drain side to the sewer side of the interceptor, a reflux valve made of magnalium is fixed which instantly opens with the least current of air proceeding from the house-drain, on the house side of the interceptor, and closes again the instant the current ceases, or when the sewer air is driven from the sewer up the house-drain on the sewer side of the interceptor. In this way fresh air is admitted into the house-drain on both sides of the interceptor, and is made to ventilate the public sewer; and in this way, too, when the ventilating current of fresh air ceases to flow in the direction of the sewer, the vitiated air of the latter is prevented from making its way into the house-drain on the house side of the interceptor.

The ventilated interceptor shown in the inspection chamber marked E, differs slightly in form, though not in principle, from the interceptor placed in the chamber marked C, inasmuch as the air forced into the house-drain between the chamber E and the public sewer D proceeds from both the chamber E and the drain on the house side of it. This arrangement is not so good as the one shown in the chamber C, because it permits of the storage of a large volume or block of air as foul as the air of the house-drain itself, instead of curtailing or reducing the volume of air to be polluted to the air volumes of the drains themselves as is done in the interceptor placed in the inspection chamber C. The present orthodox plan of ventilating drains and sewers is undoubtedly faulty, because it pollutes large volumes of air. For example, the air on either side of the public sewer D remains stagnant, and when parts of it are driven out of the drains into the sewer D, as is the case always when sewage passes from the house into and through the interceptor, those drains, etc., being always foul, on passing into the sewer these volumes of air will, and do, as a matter of fact, add enormously to the foul air of the public sewers which are thereby often rendered offensive and insanitary.



Face p. 264.

FIG. 68.—The Shone System. Method of ventilation

When, as is generally the case, the public sewers are ventilated through surface manhole covers fixed on a level with the crown of the public roads and streets grave nuisances arise. In fig. 68, the dotted lines marked (1) (1) show the brickwork forming ordinary street manholes, and the figure (2) shows the position of the perforated iron cover used to ventilate the sewer D. This plan usually ends in the ventilating openings having to be closed, and the foul air of such sewers was then, and is now, largely diverted and conducted into the atmosphere *via* the pipe marked (3) (4). The multiplication of high street ventilating shafts, however, are also objected to, as being insanitary nuisances. This nuisance, however, is removed when the drains and sewers are ventilated in the manner described.

Disposal of Sewage.—The sewage, once it has reached the outfall, has still to be disposed of, and the method depends on the situation and circumstances of the town. If near the sea and the currents are such as to quickly remove it and prevent it being brought back by the change of tide, the crude sewage may be discharged into the sea, or if at the mouth of a tidal river and no towns intervene, the quickest mode is to discharge the sewage into the river. This can be done without nuisance if the river is large, for the dilution to which the sewage is subjected, the gradual subsidence of solid matter, the combined action of dissolved oxygen in the water, fish and bacteria, will purify the sewage to a certain extent. If the town is not so situated, then this ready method of disposal is not available, and the sewage has to be purified before it is permitted to flow into a river or stream. Crude sewage should on no account be discharged into a river having towns or villages below, and should, in every instance, be purified. Purification of sewage may be classified under two heads, "Natural" and "Artificial." In both the agents on which purification depends are bacteria, which act on the sewage and convert it into simpler and inoffensive compounds ; the media, however,

are different. In the "natural" mode of sewage purification the sewage is applied to the land, and there undergoes its cycle of changes. Whereas in the "artificial" modes various contrivances are artificially arranged, so that the bacteria of decomposition and of nitrification present in the sewage, shall be placed under the most favourable conditions for purifying the sewage.

"*Natural Treatment.*"—In those parts of the Tropics where the climate is dry, and the rain not very heavy or continuous, the sewage farm is a very suitable method for disposing of the sewage, if the land is light and of a porous nature, and not stiff and retentive of moisture. Stiff clays are always to be avoided. As a rule there is plenty of suitable land available. But even in the natural treatment of sewage, certain preliminary and artificial methods have to be adopted. The land should be under-drained in order that the effluent water shall be carried away, and in order that the soil shall be sufficiently above sub-soil water to allow of a free circulation of air, but care requires to be taken that it shall not be too much under-drained, for in stiff soils this will cause hardening and cracking of the ground, with the result that the sewage will pass direct through the cracks to the underground drains without purification. Again, the suspended matter of the sewage should be removed by screening or other process, before the sewage is applied to the land. If this is not done, portions of the land are likely to become covered with an impermeable slime, which materially interferes with the percolation of the sewage through the soil, and with its aeration, and at the same time creates a nuisance. Further, care has to be taken that there is no flooding or super-saturation of the soil, for either is detrimental to the purification process and to the crops, while it also gives rise to a nuisance.

The sewage is generally applied to the land, either by what is named broad irrigation or by intermittent downward filtration. In both the land is under-drained, which

increases its porosity and aeration; that laid out for intermittent downward filtration being more deeply and more carefully drained. The difference in the two systems lies in the fact that, while in broad irrigation the sewage is distributed over as many acres as it will wet without super-saturation, having in view a maximum growth of vegetation for the amount of sewage applied consistent with due purification; in intermittent downward filtration the sewage is concentrated at short intervals, on as few acres of land as will absorb and cleanse

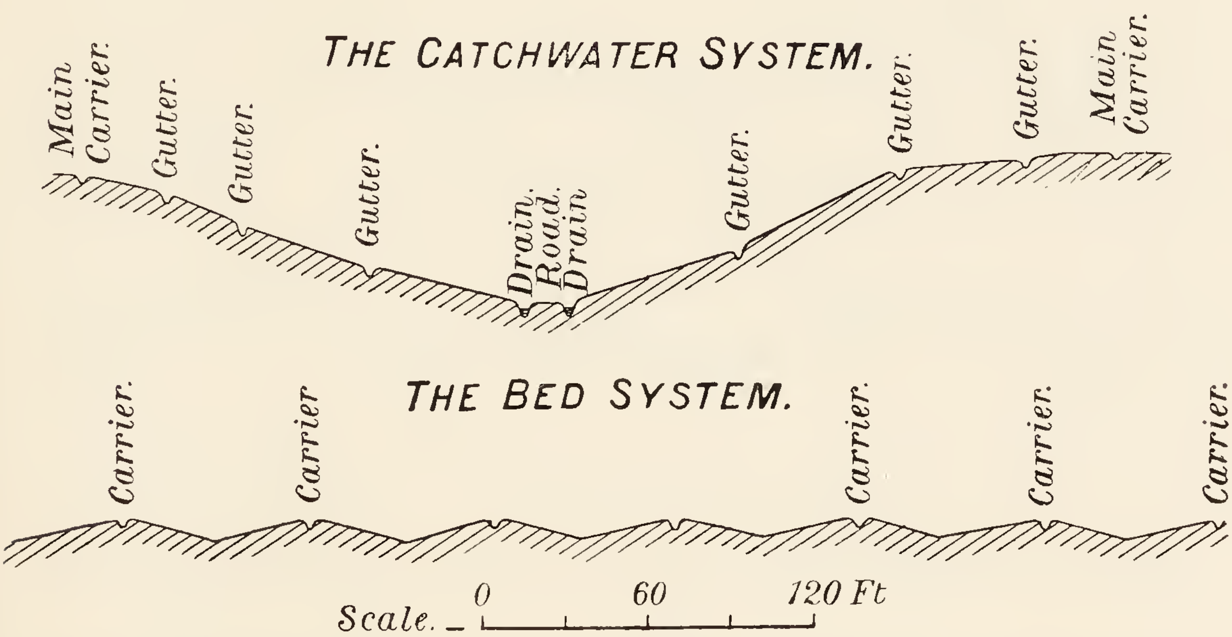


FIG. 69.—Diagram of Distribution of Sewage on a Sewage Farm by the Catchwater System (upper), and Bed System (lower).

it without excluding vegetation, but making the produce of secondary importance; the intermittency of application is a *sine qua non.*

With broad irrigation one acre of land is required for every 100 persons. With intermittent downward filtration one acre is required for every 500 persons. The most suitable land is that with a loamy soil, the next is a sandy soil, and the most unsuitable is a stiff, clayey soil.

In sewage farms where broad irrigation is adopted, the surface of the land is laid out so as to present a gentle slope, over which the sewage flows from the

carriers in a lateral direction. The sewage is generally distributed either by the catchwater or bed system. In the catchwater system (fig. 69) which is more adapted to undulating surfaces, and where Italian rye grass is the crop, the carriers distribute the sewage over the land immediately below them, and catch and intercept any sewage that may overflow from the land immediately above them.

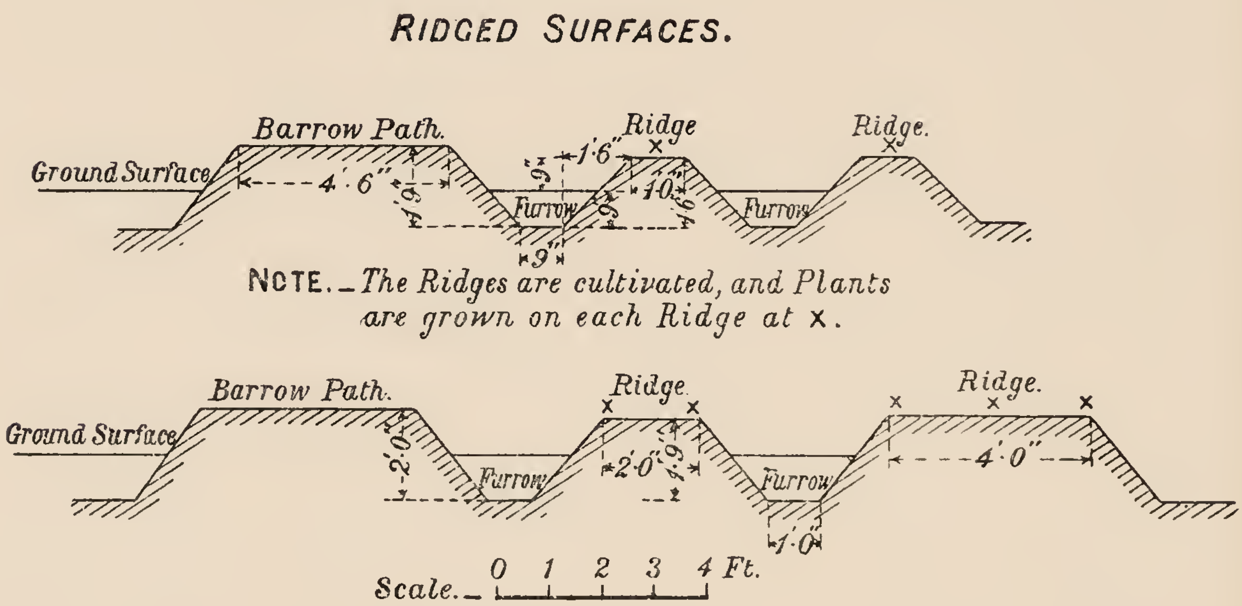


FIG. 70.—Sewage Farm, showing arrangement of Ridges and Furrows.

In the bed system (fig. 69) the sewage flows from the carrier on the ridge to cover each side slope. In the latter arrangement the distance between the furrows may be 20 to 30 feet, according to the slope and the permeability of the soil. By both these systems the sewage is brought in contact with the crops. Where intermittent downward filtration is adopted on sewage farms, the land is laid out in narrow furrows and ridges (fig. 70), and the sewage is let into the furrows while the ridges are cultivated. The sewage passes through the soil and in its progress is purified, the effluent escaping by means of underground drains, which are generally 5 to 6 feet in depth.

Three areas of equal extent are usually provided, each of which is capable of filtering the whole sewage. One

of the areas is subdivided and arranged in ridges and furrows, and a third of the sewage is applied to each sub-division for a certain number of hours each day. The ridges and furrows may be of various sizes, according to what may be found most suitable. At the end of the year they are levelled and cultivated, and another portion of the land used in the same manner for downward filtration. With the three areas, two would for two years in succession be under ordinary cultivation without sewage, and one would be filtering the sewage and at the same time growing on its ridges certain plants.

The fodder crops raised on a sewage farm may consist of guinea grass, maize, and millet (*Sorghum vulgare*), alternating with pulses. Some interesting figures are given by Mr. James, Municipal Engineer for Bombay, of the amount of fodder grown in one year on a small experimental farm of 5 acres, taking the sewage from the Matunga Leper Asylum. They are as follows :—

Maize	37·54 tons.
Guinea Grass	36·71 "
Jowar (millet)	132·97 "
Vegetables	0·56 "
Mangel Wurzel	1·91 "
Lucerne	3·95 "

The purification thus effected by the application of the sewage to the land is a complex process, which the researches of Warington, Winogradsky, Schlösing, Muntz, and the Massachusetts Board of Health have shown to be due to the living micro-organisms in the soil and in the sewage. It consists in the breaking down or digestion of the nitrogenous and non-nitrogenous organic matter in the sewage by one set of microbes, and the oxidation of the products thus formed by another set. The nitrogenous matters are thus converted into nitrites and nitrates, and the non-nitrogenous into organic acids, carbonic acid and water.

Bacteriolysis and nitrification are the terms given to the two processes involved, which consist in the albu-

minous matter and urea being converted into carbonate of ammonia by the *Micrococcus ureæ* and other microbes in the sewage, and the carbonate of ammonia being changed by the nitrifiying organisms, into the nitrate of some base, generally lime. In the soil the nitrifying organisms live in the superficial layers, and not deeper than 3 feet.

"*Artificial Treatment*," or biological method of sewage purification as it is sometimes called, consists in making use of the anaerobic and aerobic micro-organisms in the sewage itself to, first of all hydrolyze, and reduce to soluble products and gases, the albuminous and carbonaceous organic matters in the sewage, and then having broken them up into simpler and more easily oxidizable compounds, to oxidize them into still simpler ones, such as ammonia, water, nitrites, carbonic acid and nitrates, the final stage being water, carbonic acid and nitrates.

There are many plans or systems, all more or less allied which are employed to bring about these bio-chemical changes. The chief are Cameron's septic tank closed or open, Scott Moncrieff's cultivation tank, Dibdin's contact beds, Colonel Descat's "continuous" or "percolating filter," with "Stoddart's distributor," and Travis and Ault's "hydrolytic tank and oxidizer." Of these, the closed septic tank, with continuous or intermittent filtration, Scott Moncrieff's cultivation bed, and Travis and Ault's hydrolytic tank and oxidizer are the most suitable for the Tropics.

None perfectly attains the objects in view, but they are a vast improvement on the clarifying or precipitation processes which preceded them, and which are still sometimes used.

Precipitation.—At the most, chemicals only clarify the sewage. There is no process of precipitation that will do more than separate the suspended matter from the liquid matter, hence in every precipitation process the effluent is foul and contains dissolved sewage.

It is thus unfit to be discharged into a stream, and ought always to be submitted to further treatment. This further treatment is generally the application of the effluent to land.

The precipitation process is not adapted to hot climates as the nuisance attending the exposure of so much sewage, which readily putrifies in open tanks, and the subsequent removal of the sludge is likely to be offensive, unless carried out in a very isolated place. It is, moreover, costly, the precipitate or deposit produced in the tanks leaves a large amount of sludge which has to be removed and disposed of, so that the process entails considerable labour and expense. The sludge containing about 95 per cent. of water is disposed of in several ways. It may be dug out and used as a fertilizer on the land, or it may, as in London, be put into barges and taken down the river and discharged into the sea, or it may be pumped up into presses on the premises of the sewage works, and subjected to very high pressure, the effect of which is to convert about 10 tons of sludge in a semi-fluid condition into about 2 tons of dry cake which is then sold for manurial purposes, or it may be burnt in destructors and converted into clinkers, which are then used for road making and other purposes. Sometimes no chemical is used but only the subsidence tanks in which much of the suspended matter of the sewage deposits.

Septic Tank System.—The plant consists of an underground tank and a series of filters filled with furnace clinkers or coke breeze. The grit and sand in the sewage is allowed to deposit in a small chamber before the sewage flows into the tank. The pipe that conveys the sewage into the tank dips below the water in the tank, and the pipe which takes the sewage from the tank on to the filters is also below the surface. By this arrangement the sewage is disturbed as little as possible ; a scum collects on the surface, and the whole of the sewage is subjected to the action of the anaerobic microbes in

the sewage. These break up the solid matters, rendering them soluble, with the result that very little sludge forms in the tank. The gases formed in the tank consist of carbonic acid, marsh gas, hydrogen and nitrogen, and arrangements have to be provided for their escape or collection. In the latter case they may be employed for lighting or for working a gas engine. In the Tropics, however, the amount of CO_2 formed is so great that it has to be removed by slaked lime. At the Matunga Leper asylum in Bombay, the gas is collected in a tank, and is used to work a gas engine, to light the premises and buildings, and to cook the food for the inmates of the institution.

The effluent from the tank, deprived of its oxygen when in the tank, is made to flow in a thin stream over a weir or to fall through the air in a subdivided state in order to absorb as much oxygen as possible. The sewage thus charged then passes on to the filter beds, and is subjected to the action of the aerobic microbes in the filters. The aerobic filters used may be of Colonel Ducat's kind, or the intermittent filters usually set up with the septic tank system.

A closed septic tank is preferable to an open one in the Tropics, but for its effective working the gases formed in the tank should be drawn off. The nuisance arising from an open tank is often considerable owing to offensive smells from the exposure of the sewage, but more important than this is the nuisance and danger resulting from the open tank becoming a breeding place for mosquitoes and flies. An open tank is also subject to the damaging and disturbing effect which wind and rain have on the scum, and on the quiet flow of the sewage through the tank.

In the case of concentrated sewage, with a small amount of dilution, the tanks should be of larger dimensions than those in use in England, in order to give a longer time for the digestion of the larger amount of cellulose and vegetable organic matter present in the

sewage from a vegetable-eating population compared with that from a meat-eating one. When the sewage is dilute, as it sometimes is in large Eastern towns such as Bombay, where the water supply is in greater volume than in European towns, the temperature is so favourable throughout the year that the increased rapidity of decomposition more than compensates for the difference in the sewage, and the tanks may be much the same as in England.

Suitable land and plenty of it is generally available in the Tropics. When this is the case, the effluent from the septic tank or tanks may be directly used for irrigation or downward filtration, or both, or it may, after aeration, be passed through percolating filters, used continuously or intermittently, preparatory to application to the land. Circumstances will be the determining factor in each case. Where heavy rains occur, artificial filters should supplement any land purification of the sewage at least during the rains.

Mr. James, Engineer to the Bombay Municipality, from a long series of experiments on continuous filters, favours Colonel Ducat's design as giving the best results. The filtering material used is "overburnt brick," broken from $\frac{1}{8}$ inch to 1 inch cube. He, however, found it advisable to have the top layer formed of the coarsest kind and not of the smallest, as generally recommended. Experiments on Stoddart's distributor on a continuous filter with closed sides and 5 feet of filtering material of burnt brick $\frac{3}{4}$ inch cube in size gave very unsatisfactory results, which, however, were improved when the filter was so modified as to open at its sides, and the distributors were made in sections 1 foot 6 inches in width, placed about 9 inches apart and 3 inches above the filtering material. The depth of continuous filters in the Tropics should be 7 feet; the material should be coke or coal clinker, and the size of the material should range between 2 to 3 inches.

The Scott Moncrieff system consists of a small detritus

chamber, a cultivation tank filled with ordinary flint stones supported on a grating at a little distance above the bottom of the tank, and a series of filters consisting of about eight superposed trays perforated at the bottom, and each containing 7 inches of coke.

The sewage is first led into the detritus tank and from there into the space below the grating of the cultivation tank. It then is passed slowly by upward filtration to the upper part of the tank, where it is exposed to the air, and is finally discharged over the upper trays, which, being perforated at the bottom, allow of the sewage first to be filtered through the coke in each tray, and in the process of passing downwards from tray to tray to take up oxygen, and thus be aerated. The sewage is liquefied in the cultivation tank, and at the same time the organic matter in solution is converted into an unstable condition in which state it is ready to be acted upon, and converted into simpler constituents by the nitrification which goes on in the trays.

A modification of the Scott Moncrieff system has been found by Major E. Roberts, I.M.S., to work well on the concentrated sewage of cantonments in India. The filtering material used was from the grating upwards first 2 feet of old tins, bottles and pots with their open mouths directed upwards ; on this a layer of coarse clinkers or burnt clay in size for 6 inches, that of a closed fist, and for another 6 inches half this size, then on top of this a layer 1 foot deep of finer clinker graduating from 1 inch, ½ inch, ⅓ inch from below upwards, and upon this a layer 2 inches thick of broken limestone to keep the fine clinker from floating.

For the downward filters Major Roberts recommends "coarse burnt clay or clinker of such size as to pass a 1½ inch mesh, and to be rejected by a ½ inch mesh ; the whole to be fully 3 feet deep, and to have layers of broken limestone 2 or 3 inches thick at intervals of one foot throughout."

Fig. 71 represents the arrangement of the apparatus

under ordinary circumstances, fig. 72 suggests an arrangement when the gradients fail. The tank is sunk in an excavation, and the effluent is raised by a Persian wheel worked by a bullock, and is then passed on to the filters.

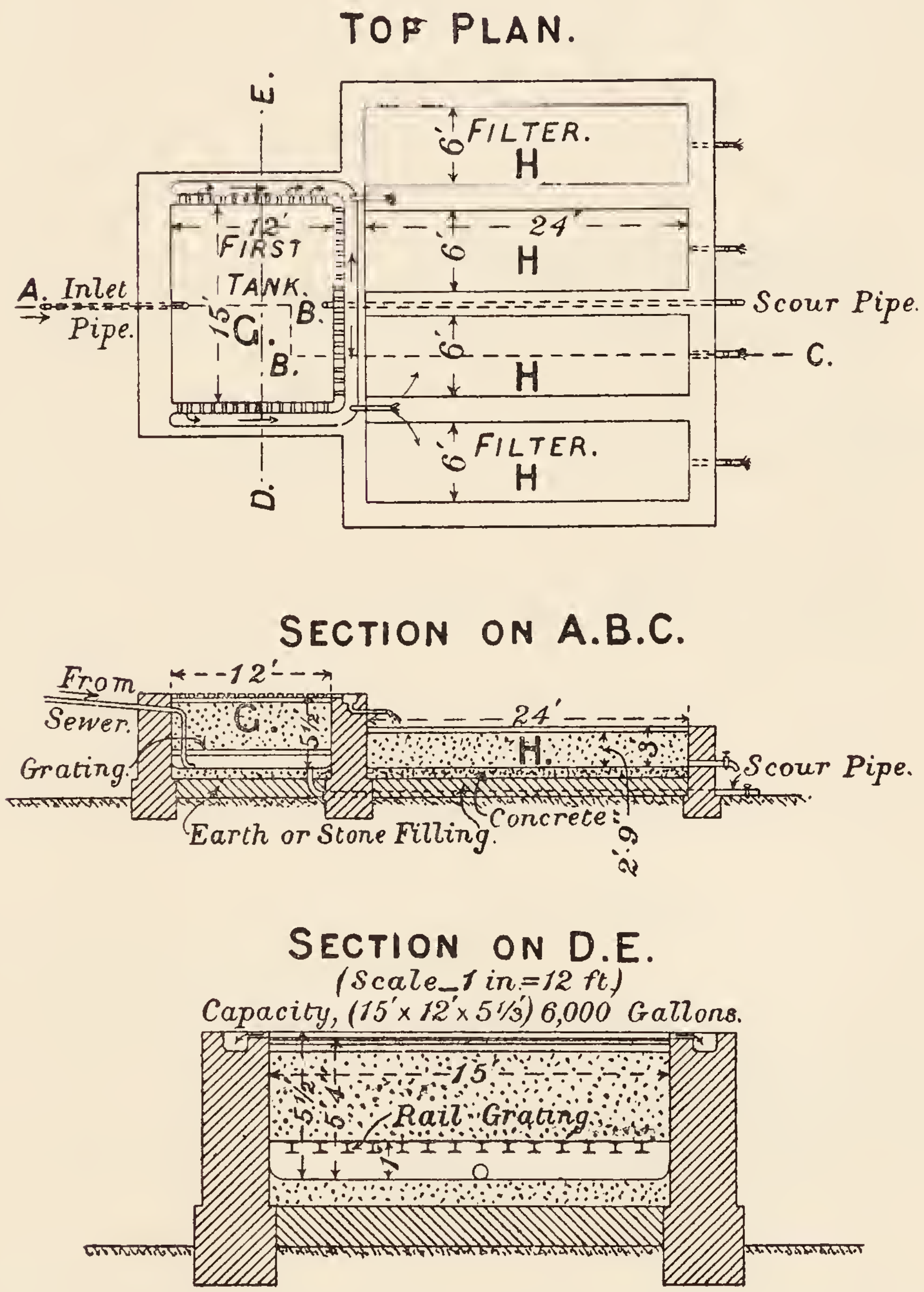


FIG. 71.—Scott Moncrieff System, as arranged by Major Roberts.

The Hydrolytic Tank and Oxidizing Beds have been designed to meet the difficulties experienced in contact beds, septic tanks and other similar systems. When biolytic tanks and beds were first introduced it was believed that the organisms contained in the sewage,

which multiply at a very rapid rate, would be able to convert the whole of the sewage sludge into inorganic compounds, soluble in water or into gases in such a manner that the biolytic tanks and beds would remain self-cleansing for a very long period and that little or no accumulation of sewage sludge would be found in them.

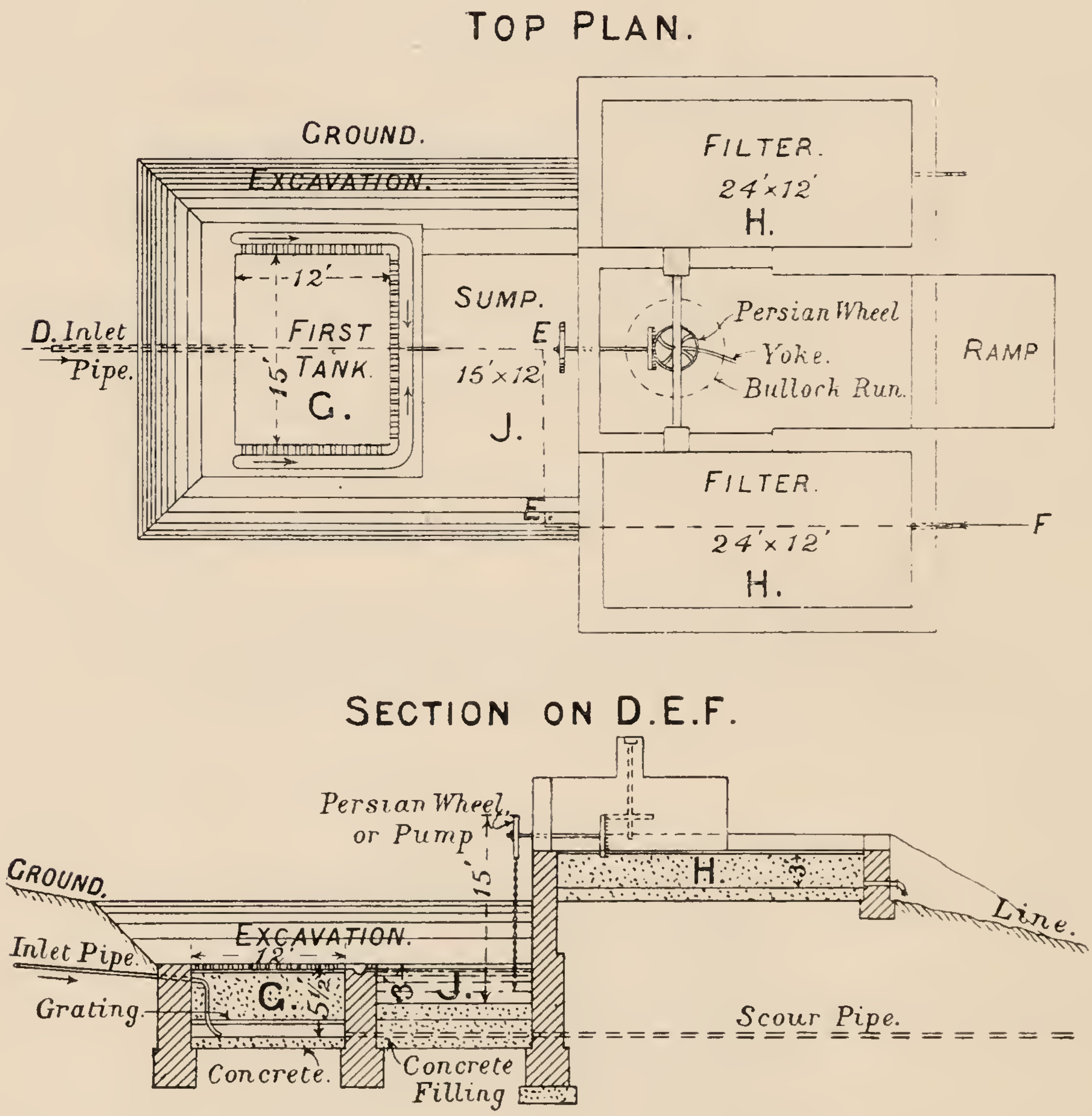


FIG. 72.—Same as preceding, but on account of gradient, sewage raised by Persian Wheel.

This belief has not been fully justified in practice, for although bacteria act very powerfully upon all organic matter and cause it to decompose their power to reduce organic matter into inorganic soluble compounds is slow. The idea that large quantities of organic matter can be destroyed by a few hours aeration in a contact

bed has therefore been given up by the more advanced advocates of the biolytic system of sewage purification.

The researches of Dr. W. Owen Travis and Mr. Edwin Ault, C.E., have demonstrated that the purification of sewage in septic tanks and contact beds is due to the retention in them of the organic and inorganic matter in suspension, and also of those matters which are in semi-solution which are called colloids and which will not deposit by gravitation but only by adhesion to surfaces brought into close contact with them. This is done very effectively in contact beds, septic tanks and by filters supplemented with sprinklers, but the drawback to these methods is that the sludge is retained in them and there is no satisfactory way of removing it from ordinary contact beds, or tanks and filters without resorting to manual labour.

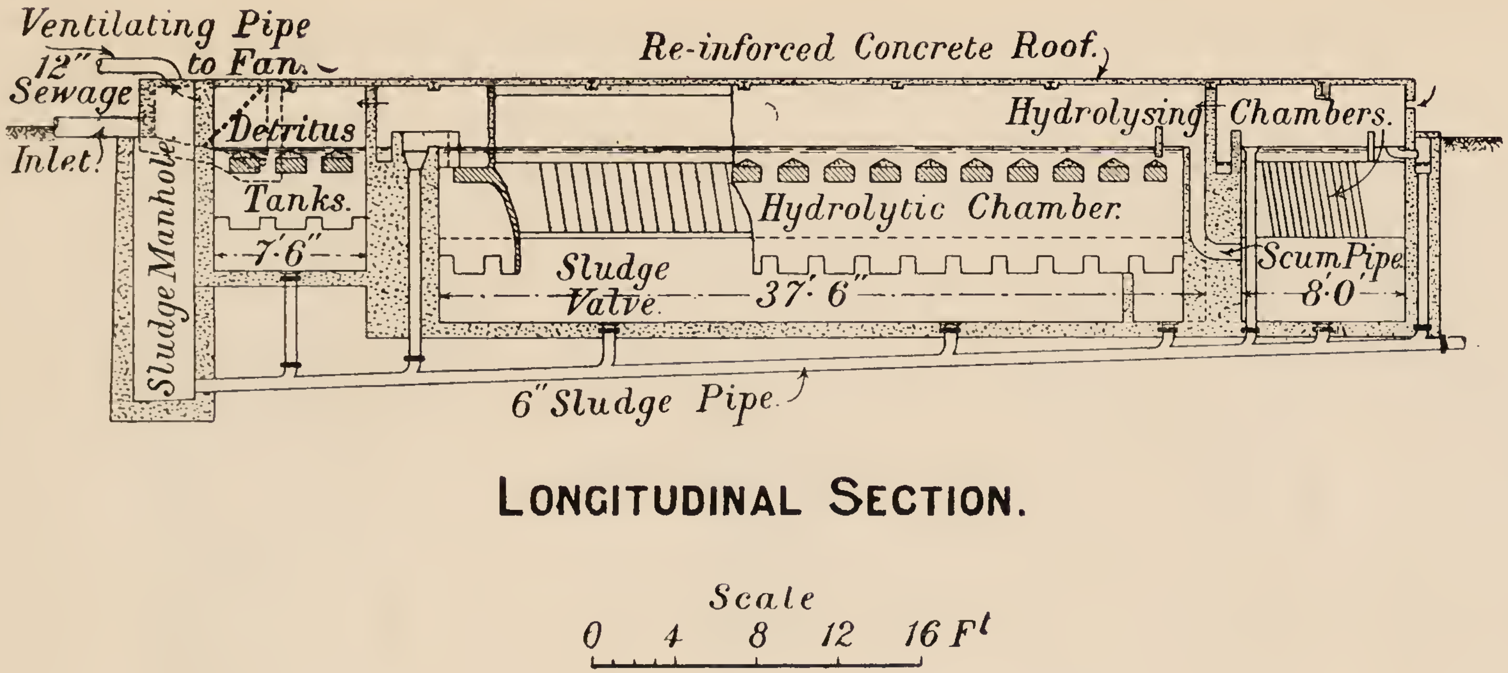
To get over these difficulties Dr. Travis uses a series of tanks and oxidizing beds, which offer the maximum facility for the deposition of sewage sludge, whether it is in the form of detritus, suspended organic matter, or colloids, and which at the same time are so arranged that all deposits collect in the bottom of the tanks whence they can be withdrawn simply by opening a valve; and the scum which collects on the surface of the liquid in their tanks is removed therefrom by floating it over a weir and dropping it into sludge pipes.

The hydrolytic tank consists of four main divisions, and the details are given in the drawing appended (fig. 73):—

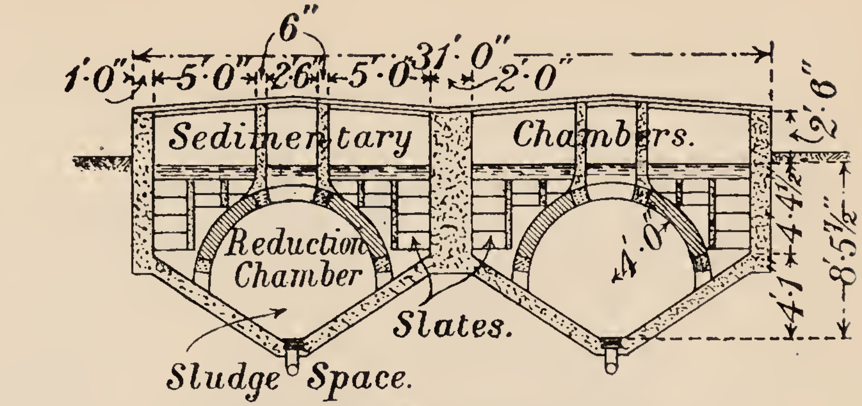
(1) Screening chamber where all large and heavy objects are retained.

(2) Detritus tank where the heavier and coarser impurities are deposited.

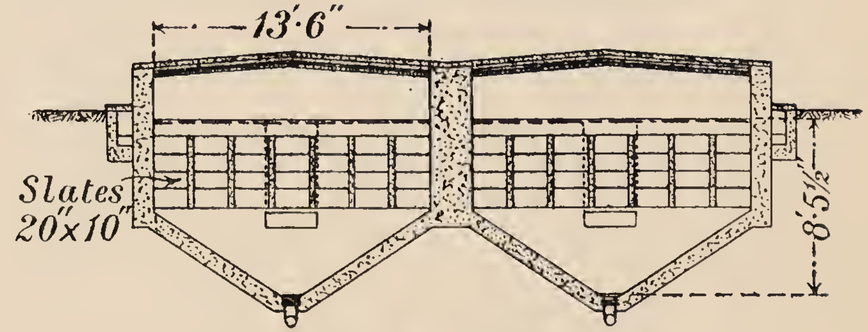
(3) Hydrolytic chamber; this latter is divided by light partition walls into three parts, two outside sedimentation chambers into which the sewage enters through suitable inlet shoots, and from which four-fifths of the sewage to be treated by them is discharged over outlet weirs,



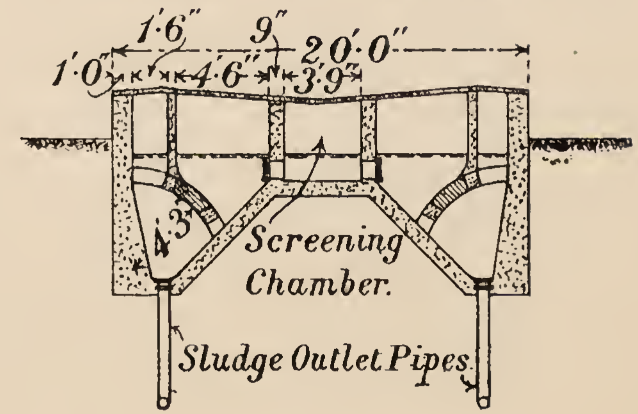
Longitudinal Section.



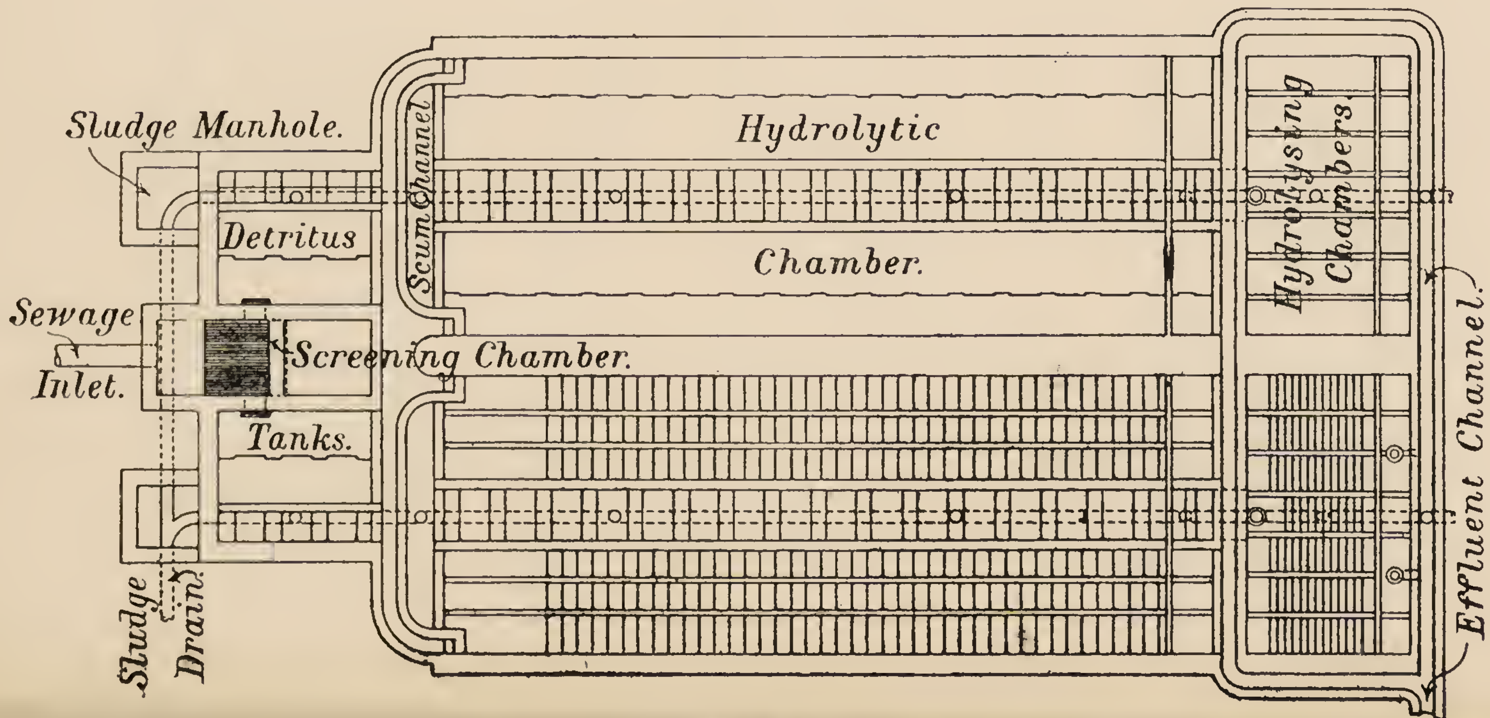
Section through Hydrolytic Chambers.



Section through Hydrolysing Chambers.



Section through Detritus Tanks.



Plan.

at the end of the tank, whilst one-fifth enters through openings in the bottom of the sedimentation chamber into the central reduction chamber, the lower part of which forms a space with sloping sides in which the sludge is retained until it can be conveniently discharged through the sludge valves.

The sewage which enters the reduction chamber through openings in the bottom of the sedimentation chambers induces a downward current of sewage in these latter chambers, which carries the sludge down towards the sludge space. The partition walls also protect the sewage in the sedimentation chambers from gas bubbles which would otherwise rise from the sludge. In this way gaseous disturbances arising from the sedimentation processes which are noticed and are unavoidable in ordinary septic tanks—where gas bubbles from the sludge rise through the whole body of the sewage—are prevented.

The colloids from the four-fifths of the sewage, which passes through the sedimentation chambers, are abstracted by means of plates of armoured concrete, and roofing slates placed vertically or slightly inclined, and the colloids which collect on them are changed by bacterial action from a state of sticky adhesiveness to one of loose granulated condition, and causes them to slide down the plates into the sludge space below. The suspended impurities in the sewage are thus concentrated in the one-fifth part of the sewage which passes through the reduction chamber, and this fifth part is then further purified in the fourth division of the tank.

(4) The hydrolyzing chamber, which is filled with vertical or slightly inclined plates similar to those of the sedimentation chambers, but placed closer together, and in this bed the colloids and fine particulate matters which are carried over from the reduction chamber are deposited in the way already described by adhering to the surfaces with which they are brought into contact, and the matter so deposited is changed by biolytic action

and falls from the plates into a sludge space similar to that in the hydrolytic chambers, arranged just below the plates.

The effluent from the sedimentation chambers of the hydrolytic tank and that from the hydrolyzing chamber is practically free from suspended matter and from colloids, and can be further purified either by means of contact beds or by sprinklers or by using the effluent for sewage irrigation.

The sludge which is removed from the hydrolytic tanks is run into trenches dug in porous ground, and this sludge very quickly loses its water and becomes comparatively firm. Ordinary sewage sludge as a rule still contains large quantities of colloids, which form an adhesive film at the bottom and on the sides of the trenches into which sludge is discharged. These slimy films prevent the water of the sludge from draining away from it, but in hydrolytic tank sludge the colloids have been thoroughly reduced and are practically non-existent, so that the drainage of water from the sludge formed in and discharged from that tank into trenches speedily penetrates the bottom and sides thereof. In this way sewage sludge is reduced in bulk, and loses its offensive odour and is gradually changed into an inoffensive humus-like substance.

The gases which are generated in covered septic tanks are insanitary and offensive in the extreme, especially when allowed to escape into the atmosphere through ordinary manhole openings; in fact, these gases have in some septic tanks caused serious explosions, which have resulted in the death of people and the destruction of costly works. With a view to suppress sewage gas nuisances at the sewage outfall tanks at Hampton, the Shone Mechanical Ventilation and Air Purification System has been adopted and given complete satisfaction to the Hampton Urban District Council. It consists in drawing air from the effluent channels through openings in the hydrolyzing chambers and through the hydrolytic chambers and

detritus tanks to the screening chamber by means of a cased centrifugal fan. In this way a large volume of fresh air is constantly drawn through the tanks, and the noxious gases which rise from the sewage sludge are drawn with the air through the fan and discharged through an air filter, which consists of a thick layer of coke kept moist by a fine spray of water. The offensive gases, which consist principally of sulphuretted hydrogen and compounds of ammonia, are decomposed by passing through the air filter, and the air leaves the filter in a practically inodorous state. Figure 73, on p. 278, shows the various parts of the hydrolytic tank referred to, and the directions the air currents are made to take in and through the tanks are indicated by arrows.

CHAPTER XI.

SOIL AND ITS DRAINAGE.

Wet Soils Injurious to Health.—The condition of the soil has an important influence on the health of a locality. This influence is dependent mainly on the amount of moisture it contains. When the soil is permanently damp or when it contains much organic matter subjected to periodical wetting it is unhealthy. To prevent these, draining and other means of protection are introduced. Surface drains, and storm water channels are constructed to carry off the rain which falls locally instead of permitting it to permeate the soil and lands, and other contrivances along with drainage are brought into use to protect low lands from being flooded. Subsoil drains are also constructed to lower, and keep at a comparatively uniform level the underground water. The subsoil drains may be loosely jointed or perforated pipes laid in deep channels or loosely laid stones forming a conduit covered with earth, or more frequently, large deep open channels. It is important to note that in the case of subsoil drains or pipes they are liable to become choked by fine silt or roots of trees and plants, and they require to be periodically cleared or dug up and relaid. Where drains or sewers are laid down for sewage, a layer of road metal around the drain or sewer will provide a channel for the subsoil water.

Causes of Dampness. (*a*) *Retentive Soils.*—The causes of dampness of the soil may be due to the retentive nature of the soil. Clay or black colton soils do not dry easily, they are difficult to drain, hence, if the land is low lying

or flat, pools and swamps are easily formed, which present the most favourable conditions for the breeding of mosquitoes, and the prevalence of malaria. Retentive soils are to be distinguished from permeable and impermeable soils, though a retentive soil comes under the classification of an impermeable soil. All retentive soils are less healthy than impermeable soils which are not retentive. Permeable soils are, as a rule, by far the most healthy. An exception to a permeable soil being healthy is when it forms a thin stratum and overlies, in a depression of the surrounding surface or at the foot of a range of hills, an impermeable stratum which keeps the water that has drained into it near the surface. Alluvial soils for instance consisting of clay and sand mixed with a large proportion of organic matter, when met with in deep valleys and hollows or in flat and low lying ground are generally unhealthy.

(*b*) *Impermeable Layer near Surface.*—The soil may be rendered damp by the impervious stratum being in too close proximity to the surface and bringing the subsoil water too near to it. The depth and movement of the subsoil water are important factors in relation to the health of the locality. Subsoil water should never be less than 5 feet from the surface, and the further down it is, provided it is within reach for a water supply, the better. Small fluctuations in the height and level of the ground water are generally more healthy than wide ranges, and should the subsoil water be very near the surface a steady level and steady flow will materially add to the healthiness of the locality.

(*c*) *Obstructed Drainage.*—In contrast to this, an obstructed underground flow leads to injurious results owing to the dampness and marshiness which follow. Obstruction to the natural drainage of the locality is often brought about by embankments thrown up for the construction of railways with omission to provide a sufficient number of outlets for the water-ways which have been interfered with. Districts, from this cause,

have changed from being healthy and free of fever to being almost uninhabitable. Wherever railways do not follow the water shed of the district ample provision should be made to secure diversion and a sufficient outlet for the drainage which is likely to be obstructed. In all new railways in the Tropics this essential factor in the health of the localities through which the railways pass should be insisted on. It is not an engineering difficulty that cannot be overcome, while at the same time the prevention of the water-logging of the foundations of the embankment is a financial gain.

(*d*) *Borrow Pits.*—Apart from interference with drainage a locality is often made unhealthy by the borrow pits and excavations frequently made on either side of the railway to supply material for raising the embankment. These borrow pits become converted in the rains into large stagnant pools and marshes, and into extensive breeding-places for mosquitoes. Arrangements should always be made to join several of the pools together and empty them into the nearest water-course. They can often without difficulty be converted into storm water channels.

(*e*) *Sand Pits and Clay Pits.*—Sand pits and clay pits excavated for material for building purposes often add to the difficulties of drainage while they form unhealthy areas on account of being breeding-places for mosquitoes. Such excavations, if necessary for material, should not be permitted in towns; they should also be controlled and regulated, and when already in existence should be filled up with suitable material, obtained from high ground in the neighbourhood, or with clinker and ashes from incineration of garbage.

(*f*) *Silting up of Streams.*—Occasionally large tracts of country become extremely unhealthy and malarious from the silting up of streams and rivers, which leads to the obstruction of the natural drainage.

(*g*) *Neglect to Keep Clear the Water Ways.*—Most frequently the unhealthiness is due to neglect; the ordinary small natural water ways are not kept open but are

FIG. 74.—NO DRAINS. Note the pool of water, suitable for breeding mosquitoes, and note the damp on the garden wall. Note also that the pool is an accumulation of water from the standpipe.

allowed to become blocked by material thrown into them, or by roads, huts, houses and other obstructions being built over them. Much improvement in the health of a locality can be effected by a thorough and systematic clearance and removal of obstructions from the natural channels of the district. A few coolies with an intelligent supervisor can do this at a small expense. Attention to the natural channels, may not, however, be enough, and in most cases has to be supplemented by land drainage, which will facilitate the flow both of the surface or storm water and of the underground or subsoil water towards their natural outlets and thus prevent stagnation and flooding, two factors which are injurious to the health of a district and to cultivation.

(*h*) *Introduction of Water Supply without Provision of Drains.*—The provision of a public supply of water without adequate means for the removal of the waste water will also render a locality unhealthy. Many instances have occurred in which a locality has first improved in health on the introduction of good water supply and has later deteriorated and become malarious because of insufficient drainage to carry off the large amount of water brought to it.

Fig. 74, taken from Dr. A. J. Chalmers' report on the sanitation of Colombo, represent a condition of things to be seen in many places.

Marshes at the Foot of Hills.—Small marshes, or small areas, with a water-logged soil are frequently brought about by the configuration of the hills and valleys, or by the nature and relative positions of the strata of the soil. They are best dealt with by constructing intercepting or catchwater drains, which intercept the flow of water coming from the high lands, and which carry it away to the lower natural waterways without permitting it to lodge and waterlog the low lands or plain stretching from the foot of the hills. These intercepting drains cut off the springs, underground water, and surface water from the high lands. They may be of the simplest kind ; for

instance, a ditch constructed so as to follow the windings and contours of the high land where this joins the plain will cut off most of the water, which is then conveyed into larger trenches and finally discharged into the natural waterways of the localities. The waterlogged low land can then be dried by the construction of the necessary number of ditches that may be required to lower the level of its subsoil water and effectively drain it.

This use of contour catchwater ditches, together with ordinary ditches, in the portion of land water-logged is a method which experienced planters have adopted for drying their lands under the circumstances mentioned. It is used much in Italy, and has been employed with excellent results by Dr. Malcolm Watson at Klang, where conditions of this kind exist. It is a method which can be easily carried out by a few coolies cutting the ditches to a proper gradient under supervision after a rough plan of the lines of proposed drainage have been carried out and agreed upon by the engineer and medical officer. If there is no engineer the work can still be carried out. The cost is small, but the results in drying the land and the consequent removal of breeding grounds for mosquitoes are remarkably good.

The ditches have to be kept in good condition, and must not be permitted to assume a switchback railway undulation, or to have their utility spoiled by being blocked or by the growth of vegetation in them. These conditions may often be seen in malarial districts.

It is not always convenient to have open ditches in certain situations, in which case deeper ones filled in with rubble stones, pebbles, gravel stones, and covered with gravel or earth, makes a good substitute so long as they are numerous enough.

Marshes in Low Lands.—Structural conditions of the soil, as well as the general slope of the surface, have to be taken into account when questions of land drainage are being considered. Thus a locality often owes its marshiness to the arrangements of the strata of the soil.

For example, in fig. 75, at the foot of a porous bed, P, lying on clay, R, the latter may come to the surface, as at D, and slope upwards. The subsoil water from the porous layer finding an outlet at this point will form a marsh. Even if no visible marsh is formed, the soil will be so damp that the area will be unhealthy. No carrying away of the rain water by storm channels parallel to the sloping ground will avail to drain this area. A special intersecting channel, as shown by the dotted line, at right angles to the arrow has to be constructed to cut off the underground water escaping at the foot of the porous layer.

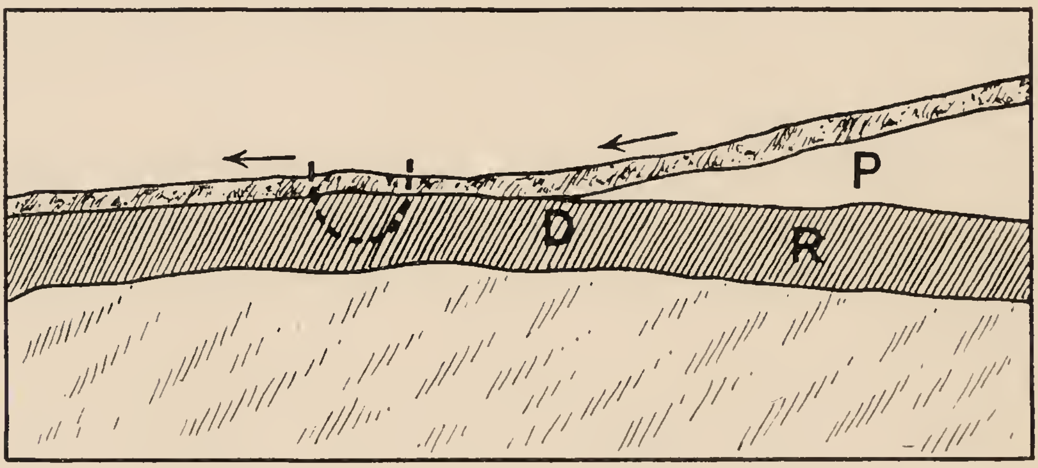


FIG. 75.—P represents porous or sandy layer ; D, point at which the clay layer appears on the surface ; R, clay layer. An intercepting channel just beyond D is necessary to prevent the formation of a marsh.

Periodical Floodings.—Certain low-lying lands may owe their unhealthiness to periodical flooding. The floodings are injurious in two ways : first, by the formation in the lower portions of pools and swamps which are the breeding places for mosquitoes ; and secondly, by spreading over the soil a fine layer of silt, which prevents the rain afterwards penetrating the soil, and this in its turn favours the formation of pools and swamps, which also contribute to the development of mosquitoes.

Drainage of Low-Lying Lands.—Low-lying lands subjected to flooding from high tides are generally protected by bunds, the drainage from the lands finding an outlet

through sluices at the outfall during ebb tides. Simple measures adopted with the object of preventing tidal waters overflowing on to the low-lying land close to a town, and the draining of this low-lying land in order to lower the subsoil water and give a free outlet to the rain water bring about excellent results. An example of this is that of Port Swettenham in the Malay States, which has been rendered practically free of malaria by the energy of Drs. Malcolm Watson and Travers, ably seconded by the engineers. Port Swettenham is a small town built on raised land reclaimed from a swamp, and adjoins swampy land covered with mangrove trees. It was so unhealthy as to raise the question of abandonment. Before doing so, however, it was decided on Dr. Watson's recommendation to construct a bund in such a situation as to prevent the tidal waters from the marsh overflowing on to the low-lying land close to the town which formed a part of the marsh, to clear this low-lying land and drain it by a series of parallel ditches with small wooden sluices at their outlets through the bund, and to fill up any portion of low-land that could not be drained. The result is that Port Swettenham has been freed from malaria.

It is not uncommon for low-lying lands to be below the level of the water into which they have to be drained, and these low lands may be subjected to periodical inundations either from river or sea, the high water level of which is above the district. In these cases catchment drains, canals, sluices, embankments, pumps, and other contrivances have to be brought into operation by the engineer. It is by works of this kind that the fens of England, the low lands of Holland and of other countries have been so successfully reclaimed, drained, and made into arable land.

Effect of Irrigation. — Irrigation may also cause a healthy locality to become fever-stricken. When this occurs it is generally due to the omission to introduce with it efficient drainage. More water is brought into a

19

district than can flow off by the outlets provided. Possibly the locality was only sufficiently drained before to carry off its rainfall, and is consequently unable, without additional drainage, to carry off the superabundant water now laid on. It has always to be borne in mind that if an increased volume of water is poured into a locality the natural channels which may have been sufficient for its drainage will likely prove inadequate, and as a result the soil will become damp and water-logged.

This water-logging will not occur when the irrigation is carried on by the individual farmer. The amount of water used is small, as it has to be raised from wells or rivers by the employment of bullocks or labourers. The soil will absorb the quantity of water thus raised. The water-logging generally occurs when irrigation is carried on on a large scale from large canals, and sufficient care has not been taken while constructing the canals to prevent them from blocking the drainage of the locality.

It is also caused by the canals being constructed so as to obstruct the drainage.

Rules and Regulations to prevent Injurious Effect of Irrigation.—Certain rules are now laid down in India for irrigation works, and their management, which, when carried out, permit of irrigation being used without any injury to the health of the district. These are :—

(1) The irrigation canals to be constructed along the line of the water shed.

(2) The smaller canals to be so constructed as not to be carried across the natural lines of drainage.

(3) Drainage cuts to be constructed along the natural lines of outfall.

(4) The supply of water to be limited to the amount required, and to the particular time needed to secure the success of the crops.

The Government of the Sudan have introduced the following regulations in regard to irrigation :—

(1) Irrigation channels should be constructed on a higher level than the surrounding land, so that when the flow of water in them ceases they may drain dry.

(2) They should be constructed of such material and in such a manner as to prevent leakages.

(3) Their banks and beds should be kept in good repair and the bed even, to prevent the formation of pools.

(4) "Dead ends" of irrigation channels should be reduced to the smallest size compatible with efficiency, so that water will not stagnate in them.

(5) Vegetation should be periodically cleaned out of the channels.

(6) Sluices should be constructed so that there is no leakage to form stagnant puddles.

(7) Where possible fish should be introduced and kept in the main channels to destroy larvæ.

(8) Lands where water is apt to stand should have proper surface drains.

(9) Crops, such as sugar-cane, rice, or others, which require to stand in water, should not be grown within a mile of any town or village.

(10) In the event of an engine or pump breaking down, particular care should be taken to deal with stagnant pools, and petroleum should be used when necessary.

(11) Malarial fever and excessive numbers of mosquitoes should be notified to the Governor of the province by the manager of the concession.

Cultivation Renders a Locality Healthy.—Apart from water-logging of the soil by imperfect methods of irrigation, cultivation of the soil tends to render a locality healthy. There is one exception to this, and it is the cultivation of rice. Rice fields are excellent breeding grounds for mosquitoes, and are consequently feverish. The only methods of protection are not to allow the cultivation to be brought close up to the villages, and to protect the windows and doors of the huts by mosquitoe-proof screens.

Effect of Disturbance of the Soil.—Large works in which there is disturbance of the soil, whether for the

purpose of erecting public buildings, constructing reservoirs, canals, bridges, railways, &c., always produce conditions which are liable to cause the prevalence of malaria. The excavations get filled with water during the rains, and the insanitary conditions under which the coolies live, produce pools of stagnant water. Breeding places for mosquitoes are thus quickly formed. If the locality is already malarious, malaria will break out at once, but if it is healthy in this respect, malaria will appear as soon as infected coolies from infected localities get engaged for the work.

Ground Air and Microbes in the Soil.—Permeable soils contain air, and the movements of the ground air are affected by fluctuations of the ground water, and by variation in the barometric pressure of the atmosphere. There is at the surface of the soil a constant interchange between the atmospheric air and the ground air, so that for those living near the ground it is important that the ground air should be comparatively pure. Therefore, in addition to freedom from dampness, brought about by subsoil drainage or ordinary surface drainage, care requires to be taken that it is not polluted by waste products from dwellings. Pollutions from graveyards, manured fields, leaky sewers, cesspools, and the filling up of hollows with refuse and garbage are common. The soil will purify itself to a certain extent, but it will not do so if overburdened. The agencies by which it effects self-purification are putrefaction, nitrification, and vegetation. In graveyards the soil is particularly rich in CO_2 and carbo-ammoniacal vapours. All soils organically polluted are rich in CO_2. Nitrates are commonly found in abundance in the soil of any long inhabited place. In the upper layers of the soil to the depth of 1 to 2 feet, nitrification by microbes takes place. The soil also contains at times other organisms besides putrifying and nitrifying bacteria.

The specific organisms of tetanus, anthrax, cholera, and enteric fever have all been found in the soil. To

cut off the ground air from a house in the Tropics, it is important that the foundations and the basement of the house shall be laid in cement or concrete or some other impermeable material.

Vegetation near houses within certain limits is beneficial. Herbage protects the soil from becoming heated and thus indirectly prevents exhalations. A grass plot around a house contributes to its healthiness. If kept in good order it gives no harbour for mosquitoes, and unlike uncovered ground is not subject to the formation of small puddles.

CHAPTER XII.

HYGIENE IN RELATION TO STREETS, HOUSES, &c.

Importance of the Subject.—In towns, many of the advantages to be derived from a pure water supply and the introduction of drainage and sewerage will be lost if the arrangement of the streets and the construction of the houses are neglected. Every old town presents examples of the very definite evils which have arisen from streets and houses being permitted to be built without regulation. While the open and regular parts of the town are healthy, the closely built, confined, and irregularly arranged parts remain unhealthy and it is found both difficult and costly to improve them. Some are beyond improvement and have to be demolished. But if these conditions are common in European towns, they are still more common in tropical countries and to a much greater extent. The narrow streets, the winding alleys, the crowding together of houses, form an insanitary labyrinth, which cannot be efficiently cleansed nor be purified by a free circulation of air.

The mischief has been done in old towns and frequently to such an extent as to be irremediable without the largest measures of demolition and reconstruction. In olden times the fashion in many parts of the East was for each king to build a new city, which no doubt originated from the fact that after a certain number of years each city became so unhealthy that it was advisable to leave it. Now, however, when the tendency is to have a permanent city, it is essential that the streets and houses shall be constructed on regular lines and not be permitted to form unhealthy and almost inaccessible

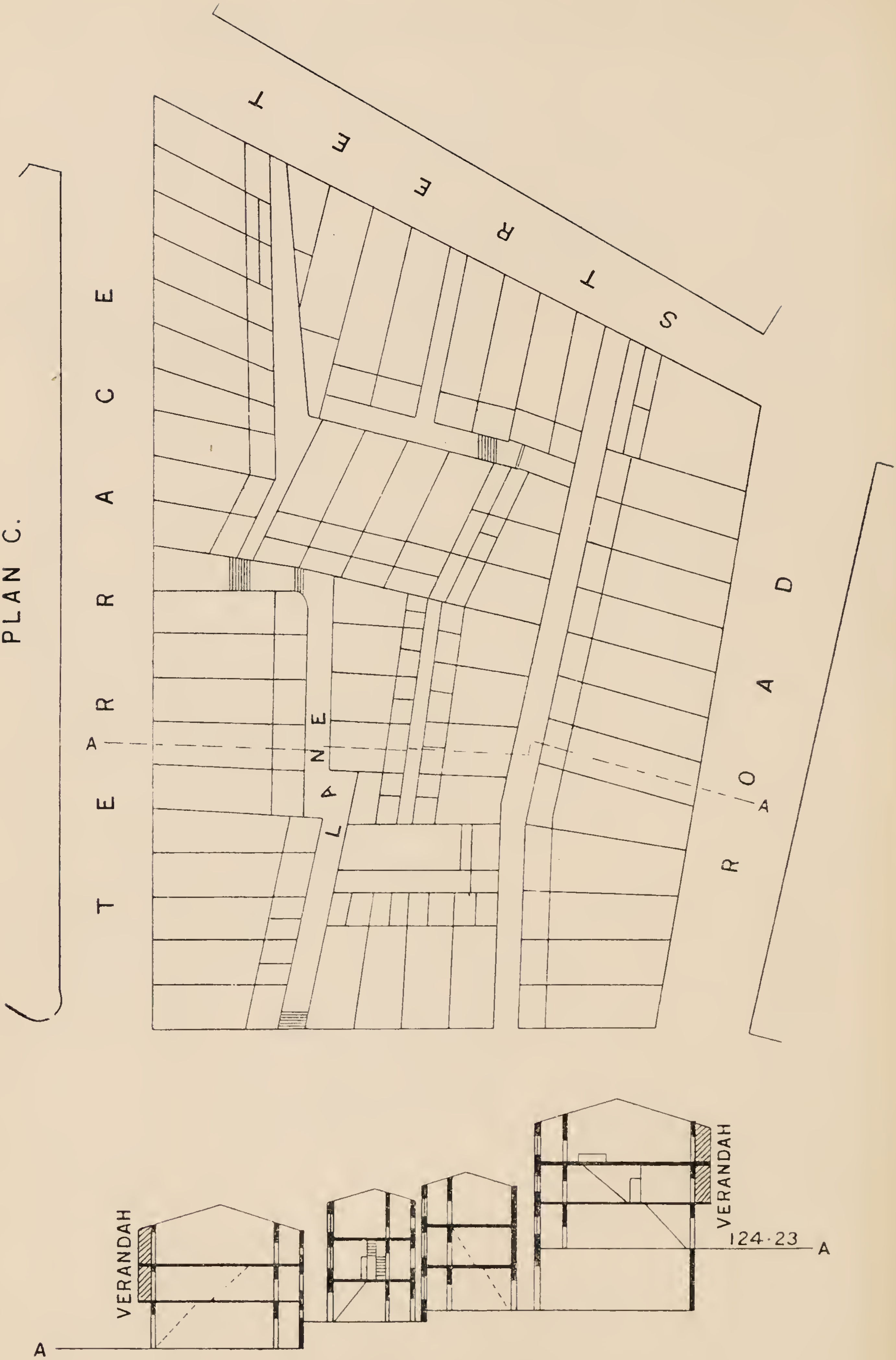
PLAN A. Fig. 76.

PLAN B. FIG. 77.

areas intersected with narrow lanes and filled up with closely clustered and badly constructed houses. Sanitarians are not sufficiently impressed with the importance of regulations for streets and houses. Much of the failure of sanitary measures in the Tropics is due to this fact. Every other sanitary measure will more or less ultimately fail if a rigorous supervision is not kept over the construction of the houses and the formation of the streets. At the time it may seem unimportant whether a house should be allowed to be built on one plot of ground or another, but each house is the unit of a street and the aggregate forms the street and area.

If streets are not laid out on a definite plan and on sanitary principles or when so laid out the houses are not subject to regulations as regards their height, depth, site, the area they cover, their relation to one another and the amount of air space to secure a free circulation of air for each, a congested area is soon formed in which there is too much crowding together of houses and too many houses on too small a space. These congested areas are always filthy and always unhealthy.

Examples of Insanitary Areas.—Plans A and B illustrate different stages in insanitary areas. Plan A is a bustee or village consisting of a number of one storied huts which are not built with any special relation to roads for each hut owner has been allowed to select the piece of land he wishes to build on, and there he erects his hut. The land-owner affects to have little interest in the matter further than being paid the rent for the land. The consequence is that as the village grows the huts spring up irregularly, often there are no roads or they are winding and of irregular width, and the huts are only separated by narrow passages. Owing to a number of tanks the bustee or village has a number of breathing spaces in its midst. Though a condition such as this is insanitary owing to the difficulty of cleansing and drainage, it is infinitely better than plan B of the same village some years later. Some passages 9 feet wide had been cut



SECTION A. A.

Fig. 78.

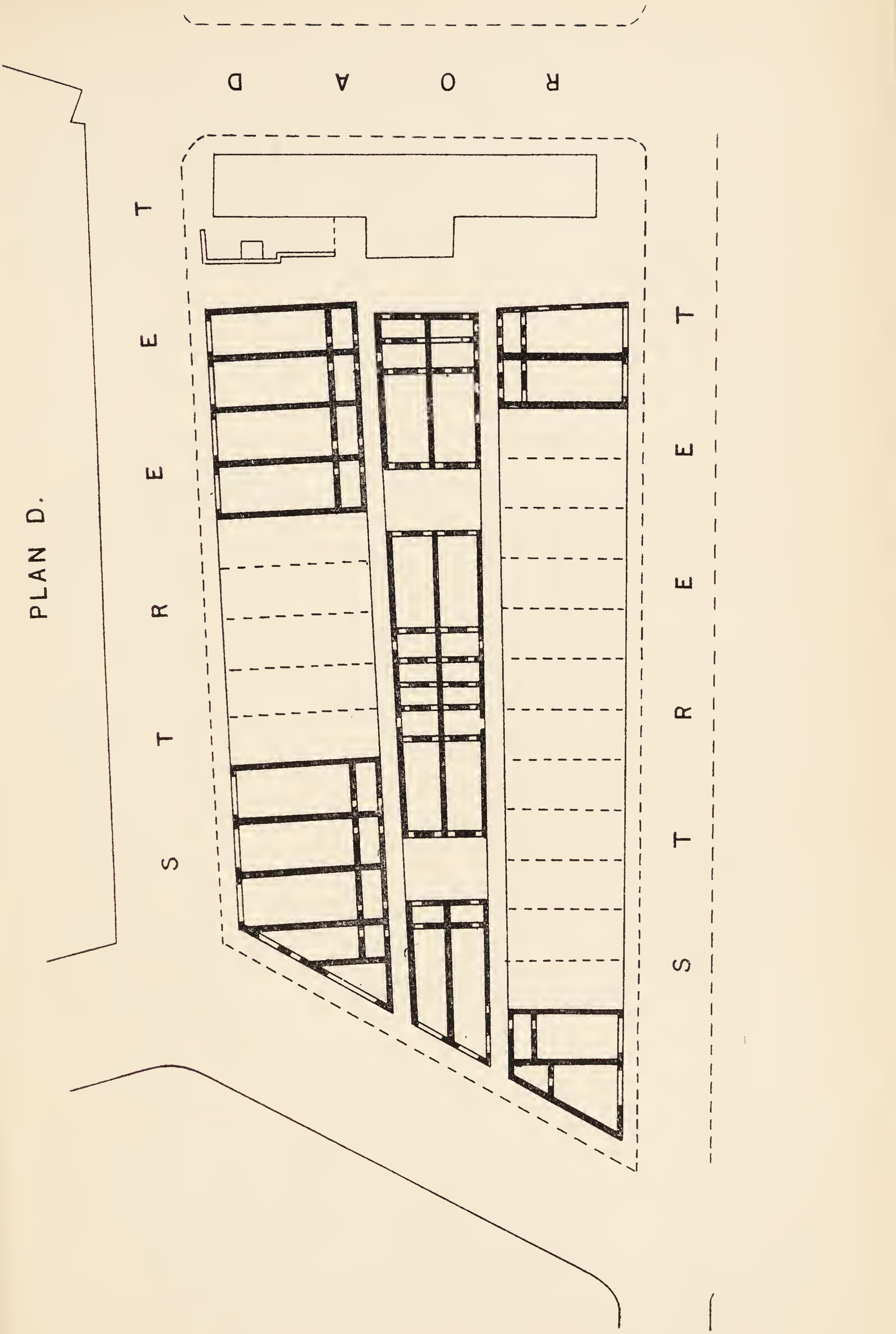


FIG. 79.

through the village, and some of the huts had been put in alignment but the majority had disappeared along with the tanks, and in their place were built two-storied brick houses facing the narrow passages. Other illustrations of insanitary areas which have been created are those of plans C and D (figs. 78 and 79).

PLAN E. Fig. 80.

Plan C represents a block in which houses were built facing wide streets. This allowed of an excellent air space behind the houses. So long as these conditions existed the area was a healthy one. The air space was, however, viewed as a waste, and houses were then built in the interior of the block, thus abolishing the air space

Fig. 81.

Face p. 301.

and leaving narrow and irregular lanes. All the houses in the block are three stories high. The result is a most unhealthy area, and a hot-bed of infectious disease.

Plan D shows how a healthy block between second and third street became an unhealthy area, by houses being built in the air space belonging to the block. Formerly the houses had light and ventilation from the street and back row; both light and ventilation are obstructed by the buildings at the back, the narrow lanes being only of use for access to the houses in the interior.

Plan E (fig. 80) exhibits a large insanitary area, consisting of many blocks. The streets are wide and regular, but the blocks present an amazing crowding together of the houses. In the narrower blocks most of the houses are back to back, while at the ends of the block the houses facing the streets have their backs abutting against the side walls of the nearest houses, and as these side walls are as high as the houses there is no open space at the rear. In the wider and more irregular blocks the arrangement resembles a piece of mosaic work, nearly every open space having been filled in by a building.

Not only are light and ventilation deficient in such arrangements, and often rendered still more so by the internal arrangements of the houses, but there are no facilities for scavenging and drainage owing to the absence of back lanes, which should always exist in these kind of blocks.

Insanitary Areas and Tuberculosis.—The influence of such buildings on a single disease is seen in the coloured plate, "Deaths from Tuberculosis," which shows the number of deaths from tuberculosis in five years in two of the narrower blocks. (*See frontispiece.*)

Mode of Dealing with Existing Insanitary Areas.—Unhealthy areas, such as those described, can sometimes be rendered healthy by clearing out a portion of the interior of the blocks and providing in addition to open spaces behind the houses back lanes for drainage and scavenging purposes (as in fig. 81). When these alterations

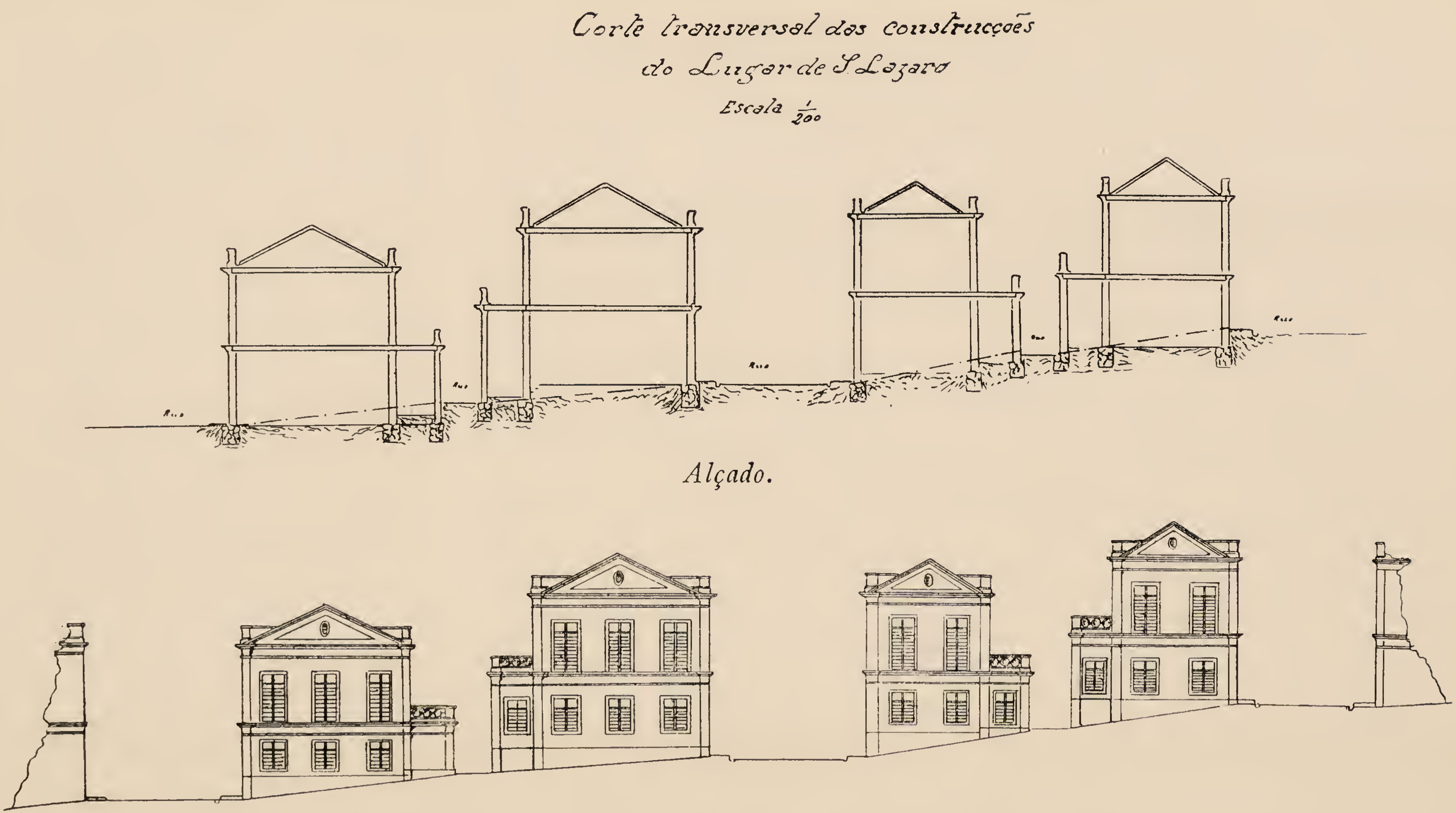

Corte transversal dos construcções
do Lugar de S. Lazaro
Escala 1/200
Alçado.

Fig. 82.

are insufficient or when, by reason of the narrowness of the blocks impracticable, then complete demolition of the area and rebuilding it on sanitary lines are the only remedies applicable. Fig. 82 illustrates such an improvement effected in Macao, where an insanitary area, consisting of narrow blocks, was totally demolished and rebuilt, with the happy result of freeing an infected locality from plague.

Control Necessary over the Growth of Villages and Towns.— If a village is already in existence and consists of one storied huts, no attempts should be made to lay down surface drains or any other kind of drainage until it is intersected by streets of at least 30 feet in width. If the huts are two storied in height the width of the street should be 50 feet. Every new hut should be set in alignment with one of these streets. If it is a place likely to increase in size and one in which stone houses or buildings will be erected, the land around the village should be laid out in regular roads, the narrowest being 50 feet in width ; 40 feet should be the minimum but there is every advantage in having the streets double that width.

If any stone houses or buildings are erected in the older part of the village, their frontage ought to be at least 50 feet from the centre of the road so as to secure, if others are built on the opposite side, that there shall be a roadway of not less than 50 feet between them, and no other hut or house should be built behind the back boundary walls of the former unless it is 50 feet from those boundary walls.

Town Planning.—The same rules apply to towns. Proper control over the growth of towns can only be obtained by all extensions of the town being made on a definite plan, which has been worked out and approved of beforehand by the local authority. There should be in the municipal office plans of all proposed extensions, and no houses allowed to be built except on the lines of those extensions. In this manner the larger lines of communi-

cation and the ordinary streets, open spaces and pleasure grounds, are provided in whatever direction the town may extend. For every town, however large or small, the local authority should have plans prepared for its future development and extension. These plans should secure the laying out on sanitary principles of those parts of the town unbuilt on. The streets should be on definite lines, the houses, while conforming in structure to the customs and habits of the people, should be arranged to secure plenty of light and ventilation, efficient drainage and a suitable position in relation to the public street or roadway, and to the neighbouring houses. In this plan provision should be made for open spaces, gardens, recreation grounds, schools, public buildings, sites for cemeteries, burning ghats, bathing ghats if near a river, public latrines, bath-houses, wash-houses, and other municipal requirements, and the class of buildings in specified areas arranged. The local authority should own as much land as possible within its area, and should be given the powers to buy land at the value at which it is rated, always supposing that this is reasonable. If the value of the land is raised to an unfair price for purposes of sale, an effective remedy is generally to be found in rating the land at the value put upon it at the time of the negotiations when these failed. Whether the local authority owns the land or not no private interests should be permitted to interfere with the extension plans which have been agreed to and laid down, and no building erected across an area planned for a future street or open space.

In town planning there has always to be kept in view the different requirements of the town. There will be the mercantile, manufacturing, residential and other portions of the town with railways and tramways to be considered. It is not a mere arranging of streets and so many sites for houses and public buildings, but the demands of traffic, business and commerce have to be provided for and these should all be combined in such a manner as to obtain as much as possible the maximum of health and beauty.

Wide Streets and Open Spaces Necessary in the Tropics.—Wide streets and open spaces in the Tropics are more needed than in Europe where the winds are more prevalent and less stagnant and where a constant interchange of air is going on owing to the air currents set up by differences in temperature between the inside and outside of houses.

The streets should be straight and intersect one another at right angles. The principal ones should be so constructed as to be in the direction of the most prevalent and healthy wind, in order that they may act as ventilating conduits to the town or village. Shade should be obtained in the streets by planting on the foot paths suitable trees giving the maximum of shade with the minimum of obstruction to the circulation of the air. Experiments in the Tropics have shown that when the air is obstructed by a building it takes a distance of one to three times the height of the building before it again reaches the same level. It is on a basis of this kind, taking the minimum and not the maximum, that the distance between opposite buildings should be at least equal to their height both in front and in rear. It is better to approach the maximum than the minimum when possible. Streets in new districts to be built on should not be less in width than the height of the proposed houses on either side but they can with much advantage be made considerably wider. No new street should in a new district be less than 50 feet in width, and the principal ones should be 60, 80, or 100 feet. In residential quarters where much open space is generally available behind the houses in the shape of gardens and compounds the streets need not be wider than the height of the house, the minimum width of the street being 50 feet, or even 40 feet, but streets which are main lines of communication and which are streets of traffic should be planned on definite and broad lines.

The same relationship of height of houses to minimum width in the rear should govern the building of

houses behind those facing the street. This is necessary not only to secure a free circulation of air but to prevent too many houses being built on too small a space; sometimes this is also regulated by limiting the number of houses that may be erected on an acre of ground.

Fig. 83 shows a house fronting a street with another house built in its rear with only a narrow passage between them. The angle of 45° which represents the same width as the height of the house, and also represents the amount of open space in the rear which should have belonged to the front house, indicates that the house in

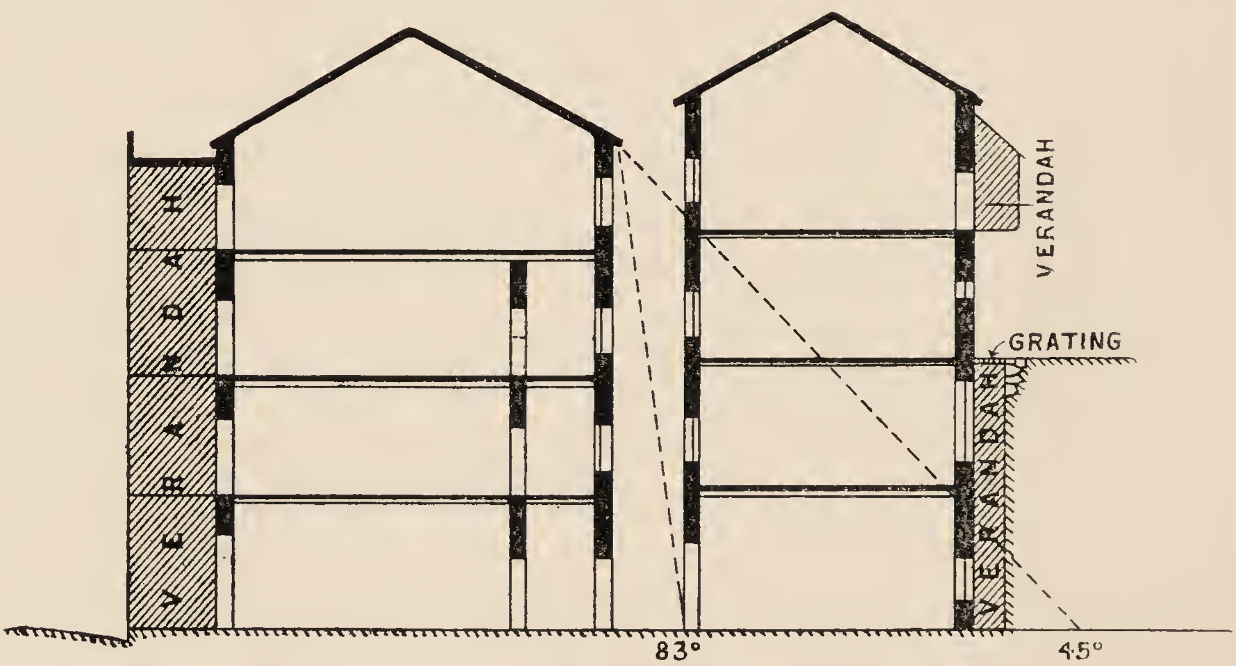


Fig. 83.

the rear ought not to have been permitted to have been built or if it had been erected first that the one now facing the house should not have been allowed to have been built in front of it. Instead of an angle of 45° separating the boundary premises of each house, the houses themselves are separated by an angle of only 83°, the result being dark and badly ventilated houses.

In the residential quarters the shapes and sizes of the building areas will be regulated by the kind of dwellings to be erected, whether for the poorer, middle class, or well-to-do, and whether joined in rows or detached. It is not in the better class residential districts that there is any difficulty in regard to space. As a rule the houses

are situated in large grounds, the roadways are wide and there are often gardens and parks close by. Even after deducting the open spaces outside the grounds, the holding area is often four times and more the road area, and the open space in the holdings double and quadruple the area occupied by the buildings. Those who can afford it fully realize the advantages in health to be derived from plenty of open space around the dwellings.

General Principles for Towns and Minimum Limits.— The general principles to be followed in other parts of the town more densely inhabited are that the blocks should not be of too great a depth. That the houses constituting each section of a block shall have at their rear a lane not less than 15 feet and not more than 20 feet wide for the purposes of scavenging and drainage. That the houses built fronting the main street shall have at their rear an open space between them and the boundary wall of the lane. That in the centre of the town in the business quarter not more than two-thirds of the house site within each boundary wall shall be covered and not less than one-third remain uncovered, and in the outer and residential ring of the town that not more than one-half of the house site should be covered. These should be laid down as minimum limits, but every effort should be made to induce house builders and owners to leave more space. Warehouses and go-downs should be placed in a different category from dwelling houses. They should be in blocks by themselves and not in blocks in which there are dwelling houses, otherwise if they are placed in blocks with dwelling houses they should conform to the regulations laid down for dwelling houses.

Back lanes are useful for the following purposes :—

(1) They facilitate (*a*) drainage, (*b*) scavenging ;

(2) Add to the air space between the rear of buildings and thus reduce overcrowding on area ;

(3) Prevent encroachments and extensions backwards, which are detrimental to ventilation and a free circulation

of air. Any extensions necessitate the acquiring of the adjoining house and not the erection of a building in the rear on the open space ;

(4) Form an alignment at the back in the same manner as the street forms an alignment in the front. The alignment is essential to prevent the lanes from being irregular and winding ;

(5) Define the limits of the boundary of each plot at the back and secure that the amount of site to be covered and left open by the building regulations shall be easily determined and insisted on.

Building By-laws for Dwelling-houses are necessary to avoid Excessive Covering of House Site, and Secure Light and Ventilation and Freedom from Dampness.—It is not sufficient for attention to be paid to the streets, back lanes, and open spaces behind houses. By-laws regulating the lighting, ventilation and drainage of the house itself are necessary, otherwise houses will be built which receive little or no advantage from the open spaces and drainage areas allotted to them. Houses are frequently in the Tropics so ill-designed as to shut out in great part the light and fresh air essential to make them healthy. They are often constructed of great depth, without lateral windows to light them, depending only on the windows facing the street, and the narrow space separating them from the house behind, when a narrow space exists, but which not unseldom is built up. When lateral windows do exist, as is sometimes the case, in long and deep houses with central corridor, the windows frequently look into narrow passages, which bring neither light nor fresh air. Sometimes the house has the windows facing a courtyard, so constructed as to provide a totally inadequate amount of light or air into the rooms. To these defects in design may be added further obstructions to light and air by partitions. The Chinese are particularly fond of sub-dividing the rooms of the house into narrow passages and windowless cubicles, and let each cubicle to a separate family. Types of badly designed houses are given in fig. 84.

From a health point of view, the defects nearly always met with are excessive covering of the site area, that is, the area within the boundary walls of the premises on

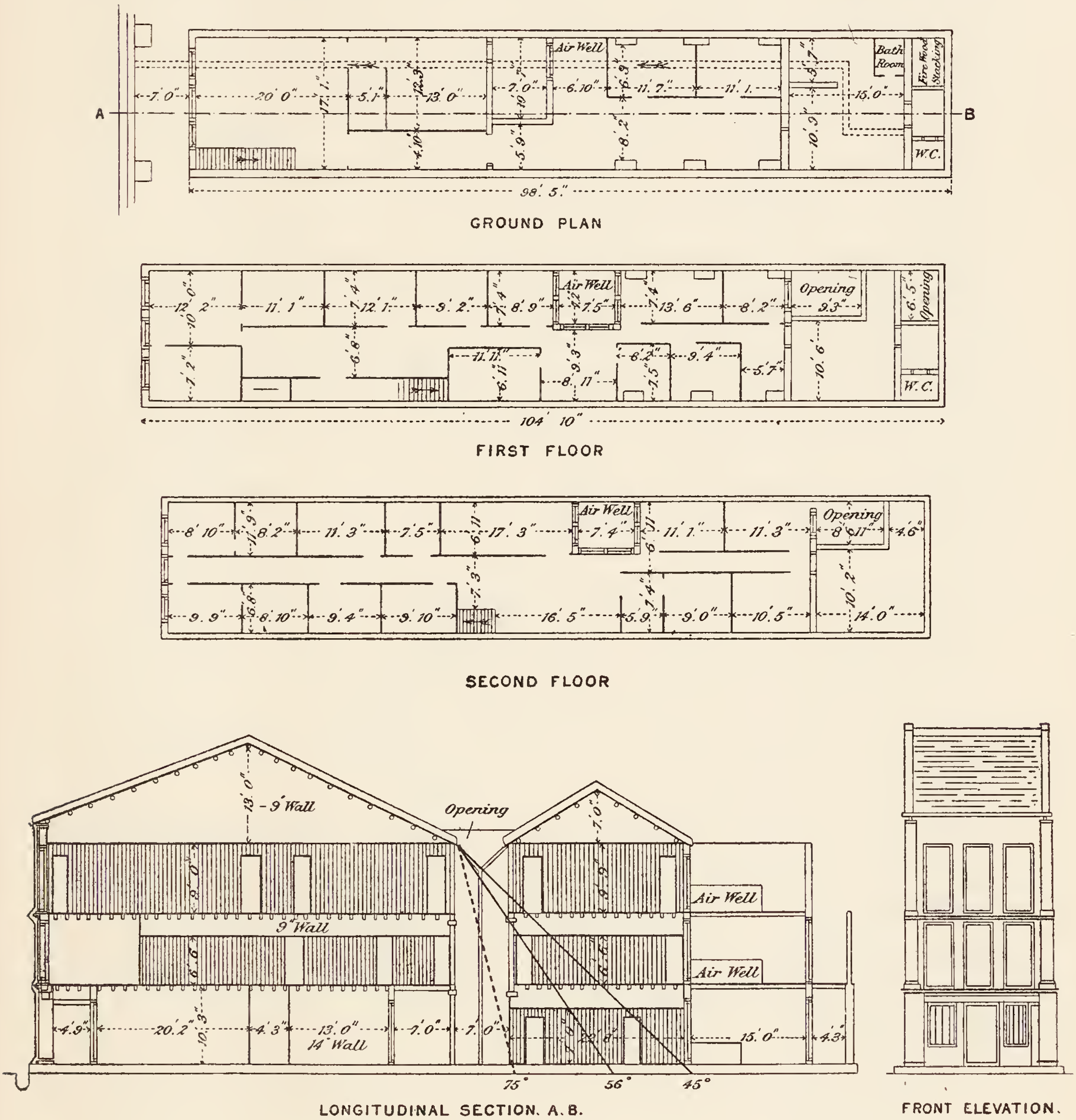


FIG. 84.

which the house is built, and the absence of provision for sufficient light and ventilation.

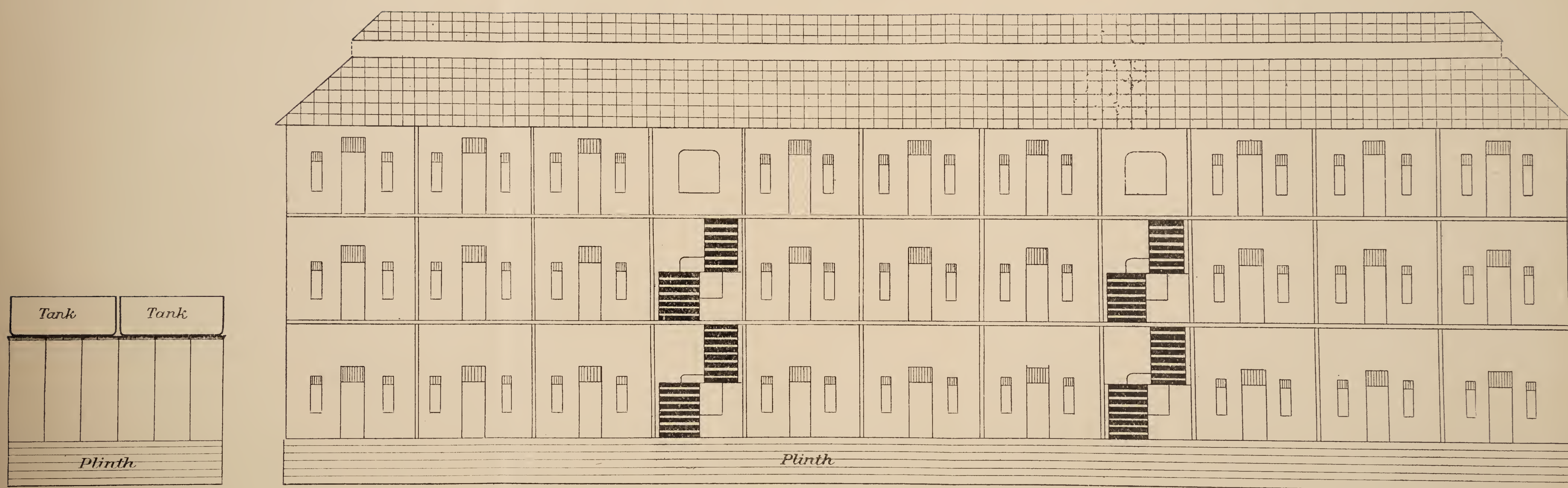
To prevent excessive building on a house site it is necessary, first, to limit and control the number and extent of buildings to be erected on a site, and to fix

the maximum proportion of the site for a dwelling-house that may be built on. In very populous parts the total area covered by all buildings, including verandahs, on any site used for a dwelling-house, should never exceed two-thirds of the total area of the site; and it would be healthier in all those places where numerous calm days prevail during the year, and the air at these times is oppressive and stagnant, never to exceed one-half of the total area. Secondly, it is necessary to regulate the amount of open space in any building so as to be proportional to the height, that is, the amount of open space in the central court and backyard should be so much if the house is one storey, so much if it is two-storied, and so much more if it is three-storied. This is best regulated by having a rule that no portion of any face of a dwelling house abutting on a court yard, shall intersect any of a series of imaginary lines drawn from the opposite face of the house, at the level of the plinth, at an angle of 56° or 45° with the horizontal. In other words, that the height of any face of a dwelling shall not exceed one and a half times the width of the courtyard, or be not higher than the width of the courtyard, measured from each face to the opposite side.

This regulation secures that the courtyard shall not be encroached on, and that if new stories are added they must be so set back that the angle remains the same, thus allowing plenty of light and fresh air into the courtyard however high the house may be. The space in the rear should be similarly regulated.

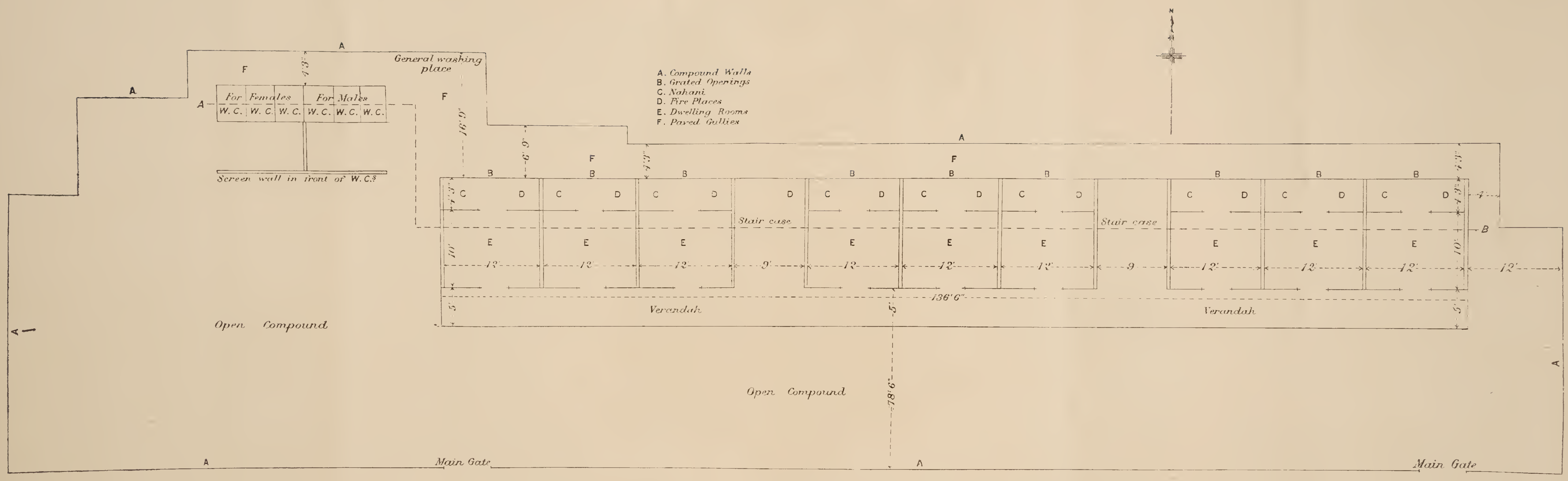
Thirdly, it is also necessary to limit the depth of a building unless it has lateral windows opening directly into the external air, with adequate space for circulation of air and admission of light, and this can be obtained by providing that no domestic building shall be erected of a greater depth than 45 feet, unless every storey of such building is provided with a lateral window or windows opening into the external air, and having a

SECTION ON LINE A.B

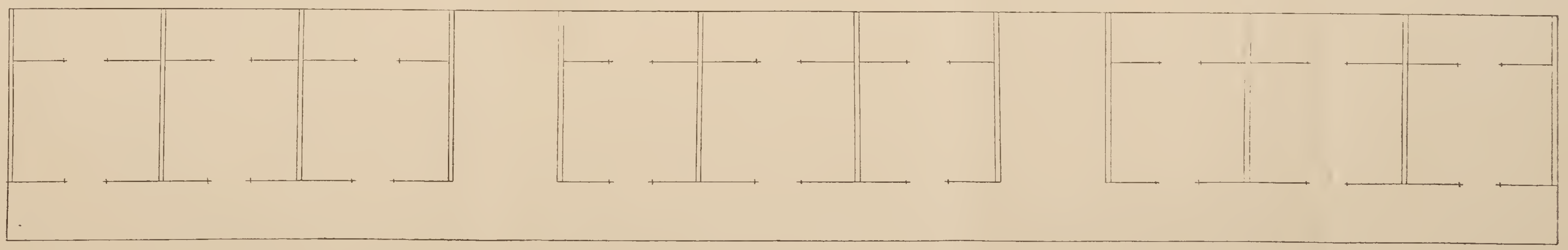


Face p. 310.

Fig. 85.

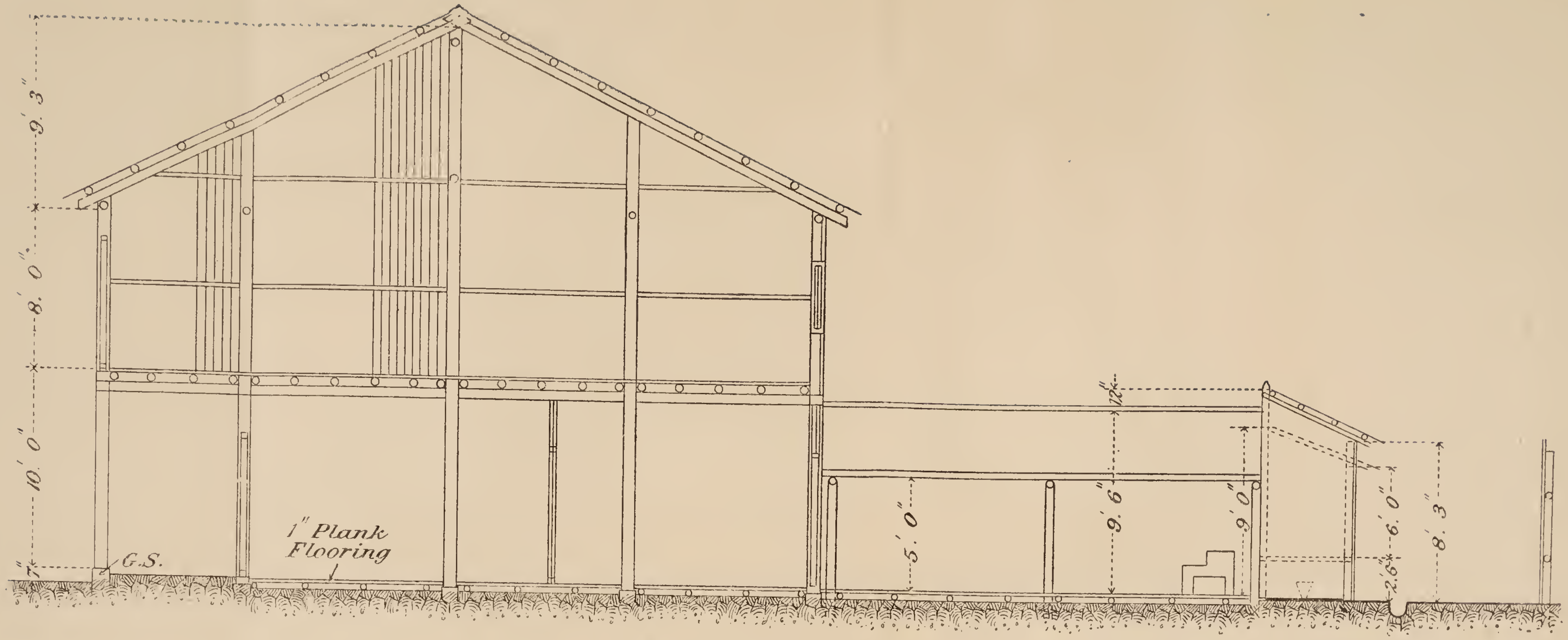


PLAN OF 1ST AND 2ND FLOORS

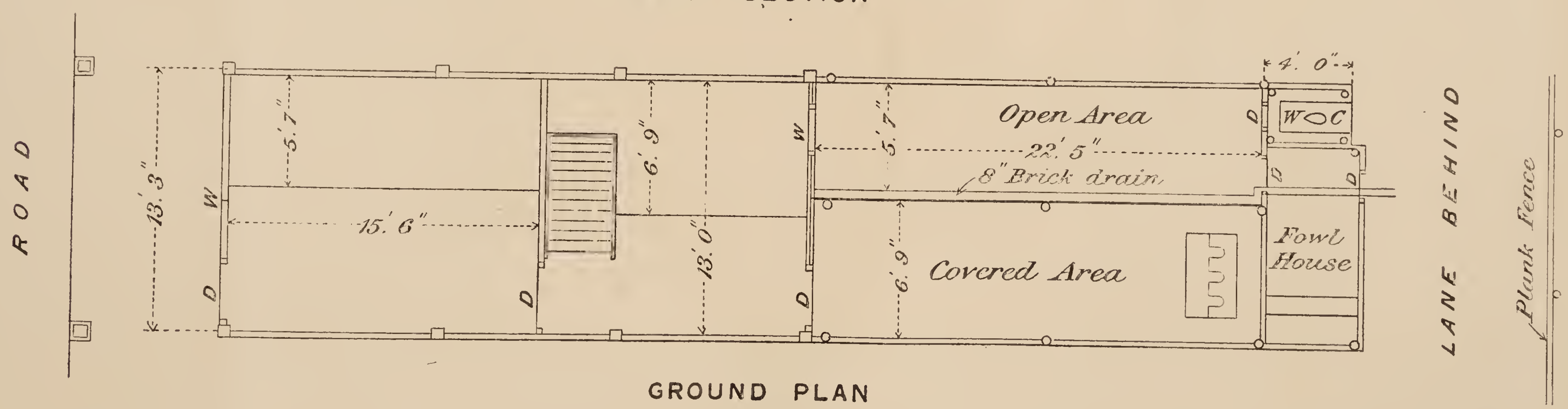


Face p. 310.

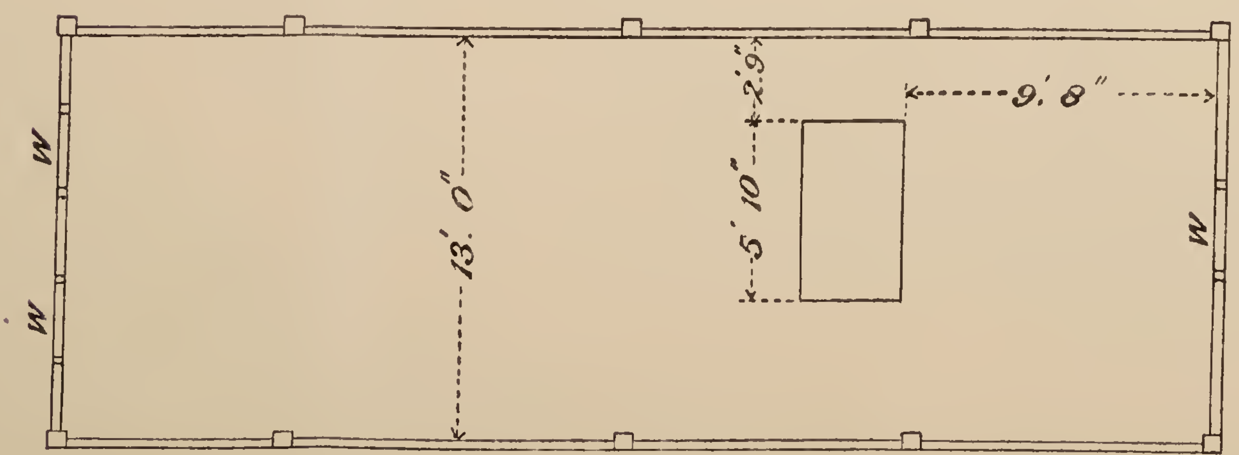
Fig. 86.



LONGNL SECTION



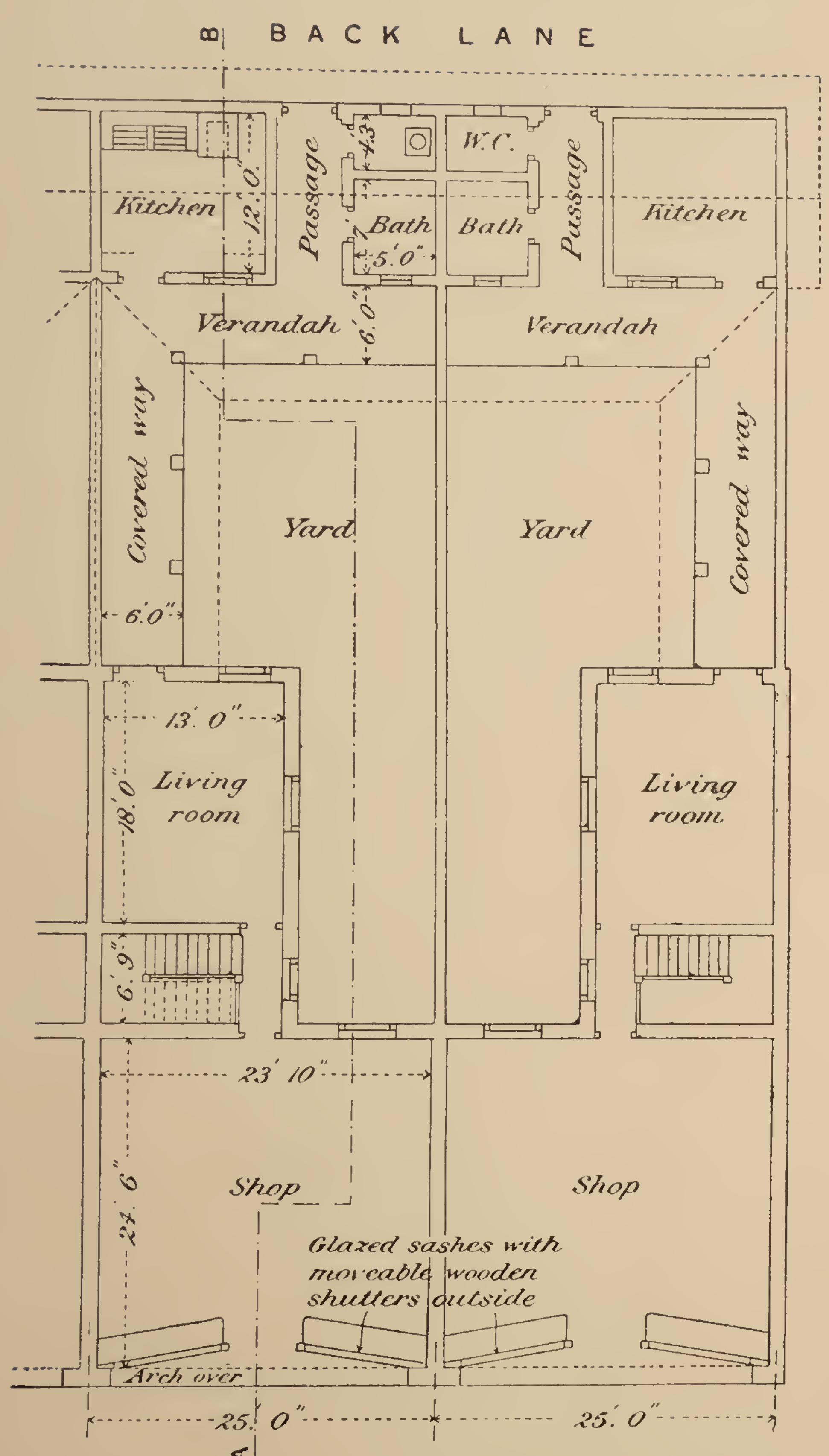
GROUND PLAN



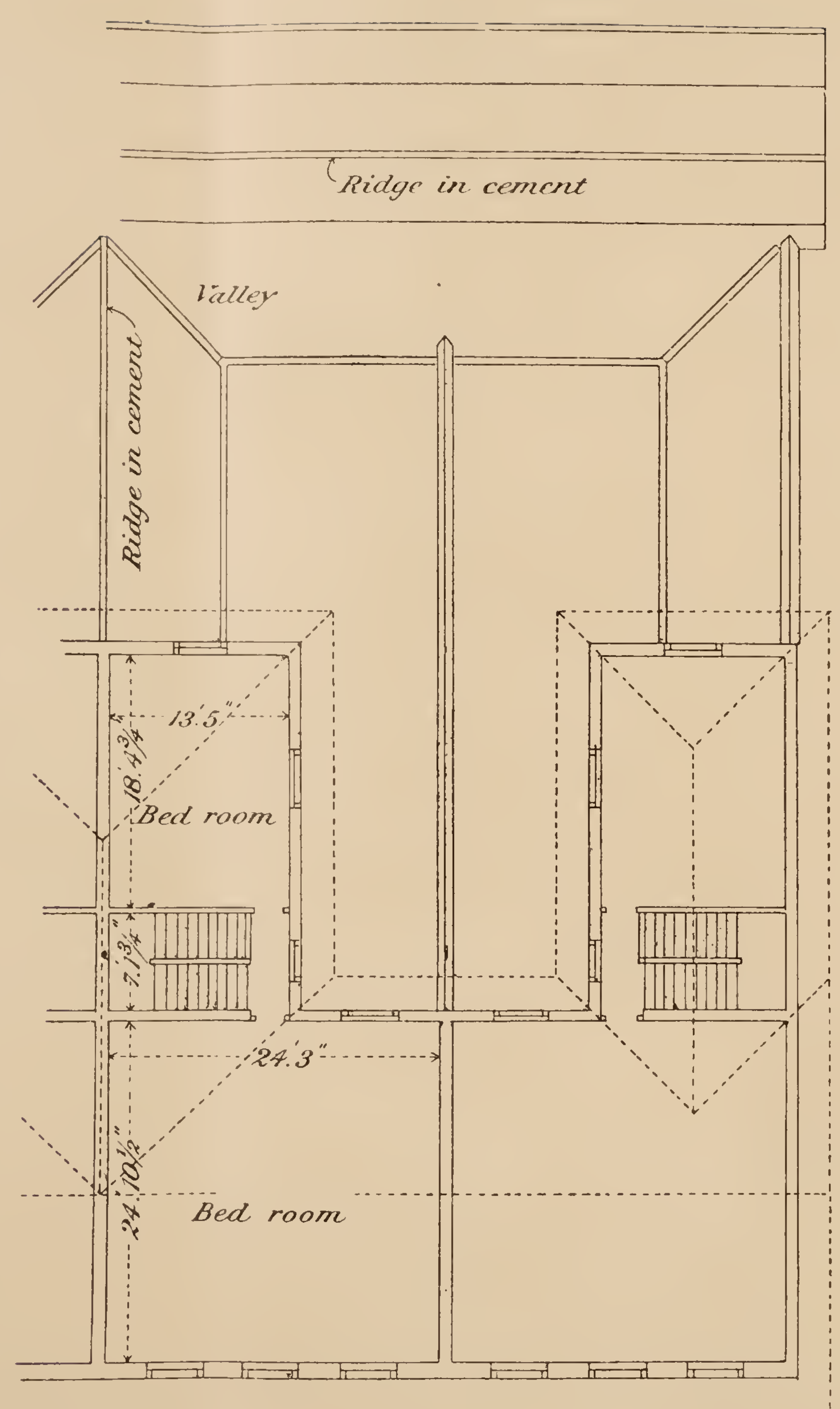
FLOOR PLAN

Face p. 310

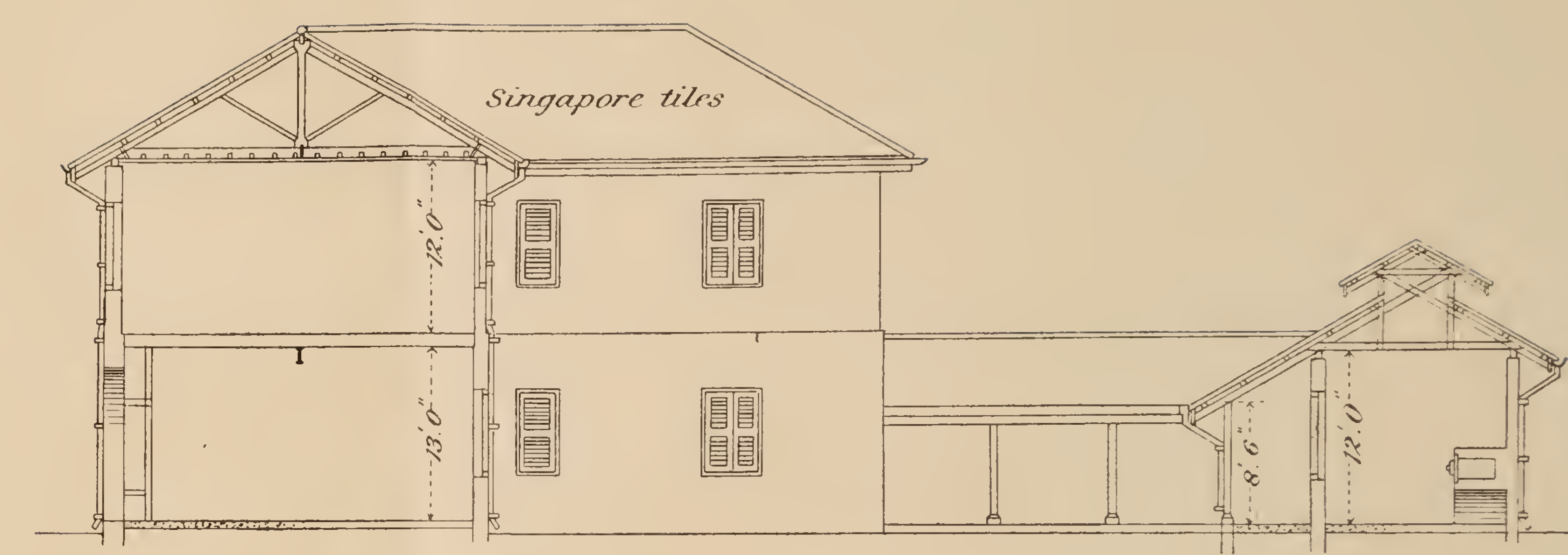
FIG. 87.



GROUND PLAN.



FIRST FLOOR.



SECTION A.B

FRONT ELEVATION

Face. p 310.

Fig. 88.

FIG. 89.

Face p. 310.

window area equal to not less than one-tenth of the floor area of such storey, in addition to windows of a similar size in front and at the rear of every storey. The accompanying plans show details of various well arranged houses, shops, &c.

The site of every house should be dry, and if damp should be raised and drained, and every house should have its foundations and walls protected from damp by a damp proof course.

Other Requisites of a House.—When a European proposes to build a house in the Tropics certain important points should be borne in mind: first, it should be well away from native huts in order to avoid infection from malarious children; secondly, the site should not be near stagnant water, nor low-lying, nor exposed unsheltered to the chilling air of a ravine or to that from a marsh. An elevated and dry site on sloping ground, but not in a hollow, should always be chosen. Even in a hilly country a site may be unhealthy if in a hollow surrounded by hills which impede ventilation, and favour stagnation of the air or water-logging of the ground. Thirdly, the rooms should always be raised well above the surface of the ground. A two-storied house in which the sleeping apartments are upstairs is likely to be a more healthy house than that which is single-storied. Fourthly, there should always be a wide verandah; and, fifthly, the servants' quarters should be well away from the house, but within the compound, which should always be large, in order that the house shall secure around it a free circulation of air. The kitchen only should be near, and connected, if possible, by a covered passage.

Foundations and Walls of Houses.—The foundations of houses require a concrete or other impermeable material to exclude damp and ground air, and the house should be raised on a good plinth.

Raising the house on pillars and arches in addition affects this even more thoroughly by permitting free ventilation underneath. The walls will otherwise become

damp by drawing up moisture from the soil. An ordinary brick will hold about 16 ounces of water. To prevent this saturation of the lower wall of a house a damp proof course is not only required in the foundations, but for at least a foot above the surface of the ground, and below the lowest timbers or floor-supports.

It is because of the absence of this damp-proof course that, as soon as the rains saturate the soil on which the foundations rest, a damp line makes its appearance on the outer and inner walls 5 or 6 feet in height, and often higher, even in houses raised on arches.

Both the soil and building material are frequently saturated with nitrous salts, which crystallize as the moisture evaporates. The bulk being thus increased, the salts burst the pores in which they are contained disintegrating the plaster, and causing the brick to crumble away, producing a most dilapidated appearance. This desquamation is due to the omission of inserting a damp-proof course as the last layer of the plinth. In the case in which a house has been built without a damp-proof course, a paint made in the following manner is sometimes applied : make a boiling solution of 4 lbs. of green vitriol or copperas to 12 gallons of water, add 2 lbs. of white resin, 10 lbs. of sifted yellow or red ochre, 8 lbs. of rye meal, and 7 lbs. of linseed oil ; stir until all the ingredients are thoroughly incorporated. Apply two coats while hot, allowing the first to dry before applying the second. The mixture must be applied in dry weather, while the walls are free of damp. A coat of silicate paint may be afterwards applied. This will lessen the effect, but complete prevention of dampness can only be carried out by the insertion of a damp-proof course between the foundation and the superstructure. The damp-proof course can be made of any impermeable material which is at hand, and which is suitable for a building. The material must be impermeable to moisture, and sufficiently strong not to break with the superincumbent weight and unequal pressure. It may

consist of cement or slates laid in cement, or with cement between them, or of glazed stoneware, perforated tiles, slag or enamelled bricks, asphalte is not good as it is apt to soften at high temperatures, and to be so compressed by the weight as to be forced from between the joints, thus destroying its action as a damp preventer. If nothing better can be obtained, tarred bricks are useful. The bricks are first heated and then plunged into a bath of boiling tar, and then rolled in dry sand. If these are not obtainable a mixture of fresh slacked lime and vegetable oil is useful. This should be well mixed by hand the day before it is wanted. It is then spread evenly over the foundation course with a trowel, in a layer about $\frac{3}{4}$ inch thick, and left for one day to set firm; after which care has to be taken in laying the first courses of bricks not to break or disturb the cement.

The walls should also be protected as much as possible by overhanging eaves.

Every house should be surrounded by a well-constructed drain to carry off the water streaming down the walls during the rains, and prevent soakage causing dampness of the walls, or the formation of puddles which would harbour mosquitoes. It should also have a space of ten or twelve feet which is paved, tiled or well consolidated with vitrified brick, and which is sloped away from the basement. A belt of sharp gravel beyond this is an obstacle to snakes. Short grass beyond this is the most suitable and most healthy kind of vegetation to be near a house. In this connection Bahama or Dub grass is useful in the Tropics, as it tends to prevent other and longer grasses from growing. Trees ought not to be so close as to obstruct the ventilation or tend to make the house dark or damp.

Roofs. — Protection against the heat of the sun is obtained by double roofs of non-conductible materials, coloured light externally, and high rooms. The heat radiated from a roof is in inverse ratio to the square of its distance. The direct heat reaching a person from a

roof 5 feet above him is four times as much as would reach him if the roof were 10 feet above him. It is accordingly important to have high rooms. The air spaces between the double roof and ceiling should be ventilated.

Thatched roofs, consisting of long wiry grass laid in bundles on a bamboo frame, or of palm leaves, are very cool and dry, but harbour squirrels, rats, insects, and other animals, and are liable to take fire. Plantain fibre, not leaves, forms an excellent roof, and is not inflammable, but it is liable to run into channels, leaks, and often requires repairing.

Corrugated or galvanized iron is used as roof coverings. The sheets should never be laid on rafters only. Such roofs render the huts excessively hot during the day and cold at night. The sheeting should be laid on close boarding, or should be lined with felt underneath, or should have an earth ceiling put under the roof.

Huts: their Construction and Arrangement.—Huts should have a plinth of at least 2 feet; this is in order that the hut shall be kept dry and that it may be properly drained. The floor should be thick and should be made of well-puddled mud, having a layer of cement over it.

In very damp places the huts may be raised on piles. A damp-proof course is to be inserted in the lower part of the walls; it may be made of hydraulic cement continuous with the impermeable floor, or of tarred bricks which are cheap for huts, or of impermeable stone set in cement. The walls are made of various materials; wood, sun-dried or burnt bricks, bamboo frame-work with timber posts, mud and wattle, corrugated iron and kerosene tins. The latter are hot and not to be recommended.

The roofs are made of tiles, thatch, or grass, or corrugated iron covered with felt. Roofs of grass and straw are very inflammable in the hot weather, but they are decidedly the coolest and the most comfortable. Cocoanut matting and plantain fibre are also liable to harbour

vermin; they should be lined inside with tarred paper or matting. The huts are best built with open court-yard with verandahs; each room being entered from the courtyard. A small opening in the outer wall near the roof, and a large window on the side of the court-yard will admit both light and ventilation. The huts should be built in continuous lines. No hut should be higher than 16 feet, and the roadway between the huts should be 20 feet in width (fig. 90). Between each hut abutting on a street, there should be at least a space of 9 feet, measuring from eave to eave. Every hut should be provided with a privy at the back. Light, temporary, and movable huts can be made of bamboo matting,

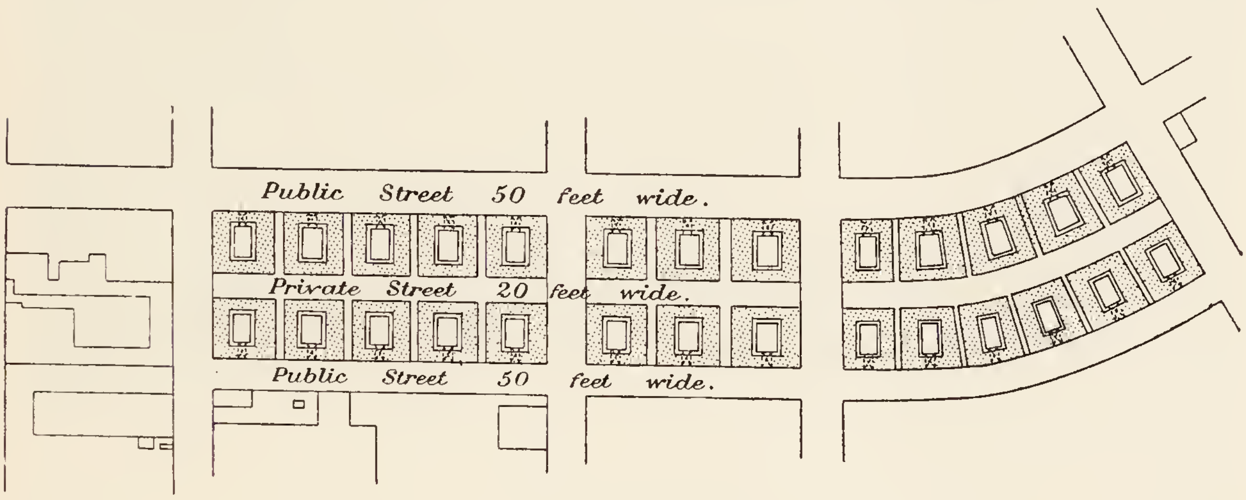


FIG. 90.

which can be rendered air-tight and water-tight by tarring or plastering with mud. Cows, ponies, goats, fowls, &c., should be housed outside the hut and its enclosure.

If the huts have no central courtyard they should have behind them an enclosure, the depth of which should be at least the height of the hut.

Animals should be kept in an enclosed compound behind the hut, and not be accommodated inside the dwelling.

Rules somewhat similar in principle to the following should govern all locations and groups of huts, which should not be permitted to be erected in a haphazard fashion, but should be governed by a definite plan as much as the houses in town.

(1) Huts should be built in continuous lines in accordance with an alignment, in their front and rear, to be prescribed by the local authority, and demarcated on the ground.

FIG. 91.

FIG. 92.

(2) Between all detached huts abutting on the roadways of the village there must be a space of at least

9 feet, measured from eave to eave. This space, together with the backward may be enclosed by the respective owners by boundary walls not higher than 6 feet.

(3) No street or road in a village shall be of less

Fig. 93.

Fig. 94.

width than 30 feet, and no back lane of less width than 15 feet, *i.e.*, in front of the hut there should be a roadway of at least 30 feet, and if two-storied huts then 50 feet, and behind the backyard of the hut a lane of 15 feet.

(4) Every hut should be provided with a properly constructed latrine, located in the backyard close to the back lane to facilitate its scavenging.

(5) The plinth of the hut should be raised at least 2 feet above the level of the centre of the road. When raised on piles, except when over water, the plinth should be the same for the purposes of drainage.

(6) No rooms should be permitted to be constructed underneath the floor of a hut which has been raised on piles.

(7) No brick domestic dwellings should be permitted to be constructed in these villages unless they are at least 25 feet from the centre of the village roadway, and conform in every respect with the ordinary building laws and by-laws for domestic buildings in regard to back lanes, proportions of site uncovered, &c. The object of this is to secure roads of at least 50 feet in width should all the huts be replaced by brick buildings.

The photographs reproduced in figs. 91, 92, 93, illustrate conditions under which none of these rules obtain.

The photograph reproduced in fig. 94 represents an improvement carried out, and shows a contrast to the other illustrations.

Markets and Slaughter-houses.—In the construction of markets and slaughter-houses, care has to be taken that they are well raised above the ground. The floors should be at least 2 feet high to facilitate drainage. They must also be impermeable to prevent soakage, and to allow of being sluiced down with water. The roof should be high to secure coolness and proper ventilation; 16 feet from floor to roof in the case of markets should be the minimum, and higher in the case of slaughter-houses. The roof should be thoroughly ventilated by ridge or louvre ventilators. Surface drains should always be kept scrupulously clean. Stalls for meat or fish should not be of wood but of impermeable material which can be easily cleaned. Latrines should always be erected at a convenient distance, kept in

proper order, and the superintendent or owner of the market made responsible for their proper use. The waste from the market ought to be removed regularly by carts : a cart or movable metallic bin being always available for refuse to be thrown into. In the case of a slaughter-house, the offal should be removed in covered receptacles.

Cow-houses and Stables.—For cow-houses and stables the chief requirements are an impermeable floor with a

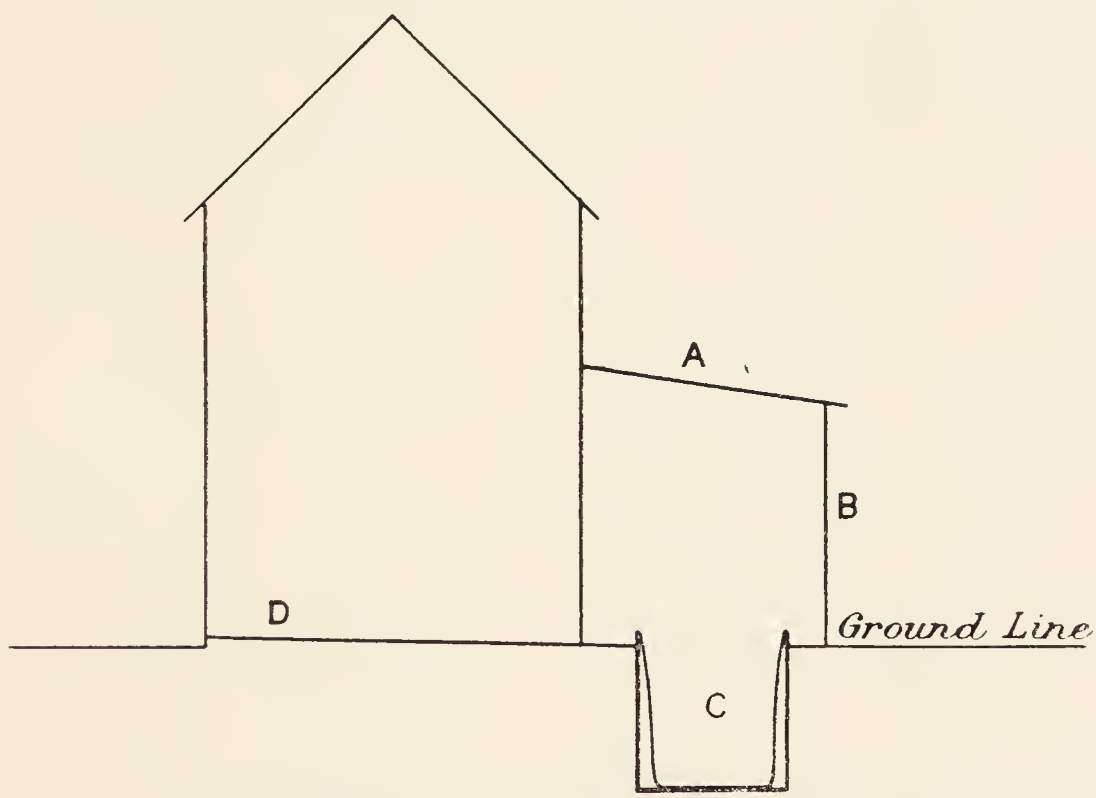


FIG. 95.—A, corrugated roof; B, angle iron or bamboo support; C, receptacle containing iron bucket; D, drain from cowshed.

good surface drain that shall discharge itself through an opening in the wall into a movable receptacle which shall be protected from rain and flood water. This should be emptied daily.

By this arrangement control is obtained over the quantity of drainage to be removed, and thus a nuisance is prevented which invariably occurs when rain and flood water are allowed to mix with the cowshed drainage.

The best cowsheds are those that are quite open, protected only by a roof, or at most by a roof and low walls, the remainder being open. The well should be at some

distance from the shed and manure that may be kept on the premises. It should not be an open well, but one properly protected, and its waters drawn by a pump. The dairy in which milk and milk utensils are kept should be separate from the cowshed and not connected with the house or hut except by a covered passage. It should be provided with a boiler for scalding the utensils and bottles used for the milk.

The cow dung can be placed in a small open shed which has a roof to protect the cow dung stored from rain, and a floor well raised above the ground so as to protect it from flood water. It can thus be dried and used for cow dung or it may be allowed to be put on the walls native-fashion and dried. As long as the cow dung is not allowed to get wetted by rain there is no nuisance. If, however, it is put on the ground and the rains come on, an abominable nuisance is created.

Hospitals, general and infectious, require the same attention to site, dryness and ventilation as houses. The distance between the blocks should be at least twice their height, and each block should be complete in its arrangements. Not more than twelve patients should be placed in one ward, and, if possible, there should be fewer. Eighty to 100 square feet should be allowed for each patient. The aspect of the hospital should be such that the direct rays of the sun will chiefly fall on the sides of the pavilion. A broad verandah round the hospital gives coolness and shade. During the rains and cold weather, when the doors and windows are shut, the ventilation is often more difficult, and arrangements should be made by which fresh air can be brought into the ward by tubes, and the foul air taken out by openings near the ceiling. Hospitals in malarious districts should be protected by wire netting.

For temporary infectious hospitals the simplest are the best, consisting of bamboo and matting. The matting should be so arranged that during the day it can be lifted up at the sides of the ward, so that the patients

are practically living in the open air with only a roof over them. The best results are always obtained in these kind of hospitals. Another temporary kind may be made of tents, the best tents are also those in which the four sides can be well raised during the day.

For permanent infectious hospitals, arrangements similar to a general hospital are required, but there ought always to be a block consisting of single rooms for doubtful cases, and there should be special arrangements for disinfection, accommodation for ambulances or dhoolies, as well as the ordinary administrative buildings and outhouses. The wards should be smaller, and the superficial area allowed to each patient should be 120 square feet.

The cubicle system, such as that adopted at the Paris Pasteur Institute Hospital, is an excellent arrangement for a permanent infectious hospital in the Tropics, where many different kinds of infectious diseases may have to be treated, and where caste prejudices have to be met.

The hospital is built on the ordinary pavilion plan, with a small verandah on each side on each storey, but instead of the long ward containing two rows of beds, ten or twelve in number on each side, separated by the central portion of the ward, it contains the same number of cubicles separated by a central passage. Each cubicle has its outside window, opening into the verandah, and its outside wall, which is the wall of the block. Its other three walls, two of which separate it from the adjoining cubicles, and the third from the central passage, are so constructed that the masonry part is only 4 or 5 feet in height, and the rest to the ceiling consists of glass. The door leading into the passage has the lower portion of wood and the upper of glass. The result is a series of well-lighted, self-contained rooms, with a well-lighted central passage, and so arranged that, while admitting of a certain amount of privacy, they are all under the direct supervision of the nurses on duty. Each cellule is provided with its own ventilation and warming, warm air

being admitted near the floor, and the vitiated air being removed near the ceiling. It is also provided with hot and cold water arrangements. There is no furniture in the room except a small table, chair, and the bed and requisites for the patient. When a bath is given, a bath on rollers is brought into the cellule and filled from the taps.

The floor of each cellule is tiled, and cleaned twice a day with water containing 10 per cent. of hypochlorite of soda. Cups, spoons, &c., used by the patient are collected at certain times of the day by a sister, who uses an antiseptic towel to take them up with, and places them in a metal receptacle carried by another sister. They are immediately taken to a special room on each floor, where they are placed in an apparatus in which they are boiled and disinfected. In the admission room the patient is stripped, wrapped in a covering, and placed in a specially constructed bed, which is then wheeled into the cubicle. The patient remains in this bed until bathed and removed to the ordinary bed in the cubicle.

When about to be discharged, the patient is taken into the bathroom, one door of which leads from the central passage, the other on to the verandah outside. The clothes worn in the cubicle are taken off in the bathroom and placed in a metallic utensil. A bath is then given, and the disinfected clothes in which the patient arrived at the hospital are put on. The patient then leaves by the door leading on to the verandah, and joins the relatives or friends waiting outside. The bath and floor of the bathrooms are washed and disinfected with cressyl every time they are used.

The most striking features of the hospital are the arrangements and the remarkable attention to detail in regard to the disinfection of everything. The nurse uses a special costume in each cubicle, and is most careful to disinfect her hands. This system is admirably adapted to the Tropics; but of course, there is no need of arrangements for warming.

Leper Asylums.—Leper asylums should not be erected in towns and should be well away from them. Leper colonies are better than asylums, if a sufficiently isolated locality is available such as a small island or tract of land on a peninsula. There can be no doubt as to the infectious nature of leprosy. It may not be readily infectious, so that nurses and medical officers can attend leprosy without any special risk, but to live with a leper under the ordinary conditions of life is almost certain to end in the disease being transmitted from the leper to the healthy.

Asylums are of little use unless the leper is compulsorily segregated, and if compulsorily segregated every endeavour should be made to make the asylum comfortable. The Hendala Leper Asylum, some distance from Colombo is one of the best in the East. It is complete in itself, having ordinary wards for the lepers, hospitals for the sick, schools, churches, chapels, temples and work shops. It is practically two villages, one of males and the other of females, in which the ordinary routine of every day life goes on under supervision and regulation.

Factories, Plantations and Emigration Depots.—For factories, plantations, and emigration depots the coolie lines have to be laid out in regular lines and constructed on the principles already mentioned. Surface drainage has to be provided, and the water supply and latrine arrangements require particular attention. The latrine arrangements will probably be on the pail system. They should be well raised above the level of the ground and protected from rain. Some one should always be in attendance on the latrines, and the excreta should be removed twice a day if possible.

It may be taken as an axiom that latrines will not take care of themselves ; however well arranged they are they will become insanitary and a nuisance if used by numbers of people unless an attendant is in charge whose duty it is to see that they are properly used and kept clean.

Pilgrimages and Festivals.—For pilgrimages and festi-

vals the chief sanitary points are to provide a hospital and hospital staff for emergency and epidemic diseases; to provide a sufficient staff of officers and men for supervision and inspection work, to regulate the tendency to overcrowding by preventing lodging-house keepers taking in more lodgers than their accommodation provides for, and to provide a sufficiency of latrine arrangements; a pure supply of water, and a staff for general conservancy with a police patrol to prevent the commision of nuisances. The latrines should be arranged on the dry earth system and may consist of a series of bamboo matting compartments. Urinals should be kept free of odour by placing in the utensils a small quantity of water, about one-sixth of what they will contain. Disinfectants such as cyllin or kerol may be added to the water. Sanitary patrols on duty day and night for periods of six hours each are necessary to superintend the work and see that the various establishments are carrying on their duty. For success nothing must be left to itself, everything should be planned out and arranged for beforehand. The camps are divided out into sanitary areas, and each part must be regularly visited to ascertain that the men and women in charge of the latrines are keeping them clean; that there is no sickness in the lodging-houses, and if there is, that the patient is removed; that the rules laid down for the lodging-houses are obeyed, and that cleanliness is obtained. The number of carts, cleaners, scavengers and inspectors must be all carefully reckoned on the approximate number of pilgrims likely to be present, and any daily increase must be noted with the object of providing the necessary staff and appliances. Lodging-houses must be registered, the number of lodgers or pilgrims they accommodate fixed, and their ventilation, drainage, water supply and privy accommodation satisfactorily arranged before they are licensed.

CHAPTER XIII.

SANITATION OF JAILS.

Construction of Jails from a Health Point of View.—Jails in the Tropical English possessions were formerly constructed to radiate from a common centre, the type having been adapted from that of the English prisons. But tropical jails are now built in separate blocks in parallel, with their front or back against the prevalent wind in order that the dormitories, workshops and hospitals may have the benefit of the greatest perflation of air. The site selected should be a healthy one, the immediate neighbourhood clear of buildings and as free of marsh and ponds as possible. If these exist they should be drained or filled up. The site area should be at least 50 square yards for each prisoner, and the dormitories 36 square feet for each prisoner and 54 square feet per prisoner for the hospital. These figures are laid down by the Bengal Jail Code for Indian jails. For single or solitary cells 75 superficial feet and a cubic space of at least 1,000 feet is required.

Taking these figures for the dormitories and multiplying by the number of prisoners to be put into a dormitory, the superficial area or size of the dormitory is easily determined. Similarly if the number of prisoners to be allotted in a block is multiplied by the 50 square yards of site area required for each prisoner the distance between the buildings can readily be calculated.

The materials used for the construction of the jail should be dependent on the locality and what can be obtained. It is by no means necessary, nor is it always

possible, to have a masonry building or a masonry wall around the prisons. Excellent results can be obtained out of bamboo, wattle and mud, or out of corrugated iron with suitable lining of the roof to lessen the intensity of the heat. Corrugated iron roofs for dormitories require no lining, and the thinner they are the easier they are to cool. The material may well be left to the engineer, who will be able to employ that which is most ready at hand, as long as it secures dryness, coolness, cleanliness, proper ventilation and non-inflammability.

The workshops should be constructed so as to obtain their lighting from the north, be well protected from the sun in other aspects, and to have ample ventilation from the sides, which should be open as much as possible. To secure working in the open air as far as practicable with proper protection from the sun, should be the object in view in planning a workshop in the Tropics, which plan was adopted in the Presidency Jail of Calcutta. Each bay had a corrugated iron roof supported on angle iron pillars, the northern exposure of the roof having a large window which opened on a pivot. The supporting pillars were 14 feet high to the eaves of roof, and the separating walls of the bays were about 7 feet high, so that the remaining 7 feet were open all round for ventilation. The superficial area allowed for each prisoner in the bays was 50 square feet. The bays were 20 feet wide. Fans were placed along the shafting for the purpose of putting the air in motion.

If a workshop—corrugated iron—is used, it should be about 14 feet in height to the eaves, with plenty of side ventilation.

The dormitories should be 20 feet wide and 12 feet high, and there should be only two rows of beds, one row near each side wall, with a good central passage. Dormitories with more than two rows should not be permitted, for their ventilation is always defective. Ten square feet of ventilation area is provided for each prisoner, and the ventilation area is calculated by taking the area of

openings, including grated window openings and grated doors, adding them together, and then dividing by the number of prisoners. The windows on opposite sides should go well up to the ceiling to ensure thorough ventilation.

In malarious and unhealthy districts it is best to have the dormitories raised from 14 feet to 16 feet above the ground, and the windows screened with wire netting. In such cases the dormitories would be on the first floor and the workshop underneath on the ground floor, care, however, being taken that there is no communication between the ground floor and the dormitories. When the ground floor is used as a workshop, the ceiling of the workshop should be at least 14 feet above the floor.

The size of the dormitories and the number of prisoners they contain is governed largely by the size of the jail and administrative requirements, the regulations as to superficial feet per prisoner and ventilation area always being maintained.

The first-class district jails usually contain 500 prisoners and the central jails 1,000 prisoners. The size of the dormitory varies from that containing twenty prisoners to that containing from sixty to eighty. The number and size of the different gangs is governed by the administrative factor, the convicts being split up into industrial, cooking, scavenging, garden, hospital, and convalescent gangs, &c., generally arranged for watching and administration purposes. For like reason, these gangs not only work, but where possible sleep in the same dormitory.

In the construction of jails, provision should always be made to secure efficient ventilation of the dormitories when the windows are closed on account of the severity of the weather. The calculation for efficient ventilation should not only be made on hot weather conditions when every opening for the perflation of air is open, but also on those prevailing during the cold weather, when draught and cold is likely to be injurious. It is important to control the ventilation according to the season pro-

viding the maximum openings for ventilation necessary during the hot weather and rains, when the air is frequently stagnant or nearly so, and reducing this maximum by temporary reduction of the openings during the cold weather. The effect of any reduction in ventilation is generally judged by visiting the dormitories several hours after the prisoners have been locked up in them, and noting the condition of the air as it affects the sense of smell. A perceptible odour indicates too great reduction of the ventilation openings. These ventilation openings are often reduced by partially and temporarily building them up at the commencement of cold weather or by the use of mats covering them. Protection of the opening from rain is effected by louvres, attached to the outside of the openings.

Comfortable and healthy dormitories were constructed in the Calcutta Presidency jail on the following plan. Angle iron verticals were made to support a curved roof. Underneath, the floors were raised a foot from the ground, and at the sides and ends walls of brick were built up to about 3 feet above the floor, and on these short brick walls were carried to the eaves of the roof with open intervals between them, and strong galvanized iron netting of an inch mesh was stretched tightly between the uprights, affording perfect ventilation and perflation of air. Each end was provided with a wide grated door. During the hot weather and rains the netted openings had no protection whatever, but in the cold weather blinds made of coarse sacking were fastened on the *outside* to prevent the prisoners pulling them down, arranged so that they could be dropped to prevent undue draught and chill; sufficient ventilation was left between the top of these blinds and the eaves of the dormitories. In unduly cold weather the prisoners are provided with an extra blanket and woollen clothing.

The Indian jail is usually surrounded by a high wall 15 feet in height, and the different sections of the jail are divided by interdivisional walls about 9 feet high.

When interdivision is required it can more advantageously be effected by open wooden palings or iron railings than by solid walls which obstruct ventilation and perflation of air, besides adding to the intense heat thrown off by radiation.

Water Supply.—Water for a jail unless from an unimpeachable source should be sterilized. It is not absolutely necessary to sterilize more than is needed for drinking purposes, which may be set down at 1 gallon per head. The remaining quantity of water for general

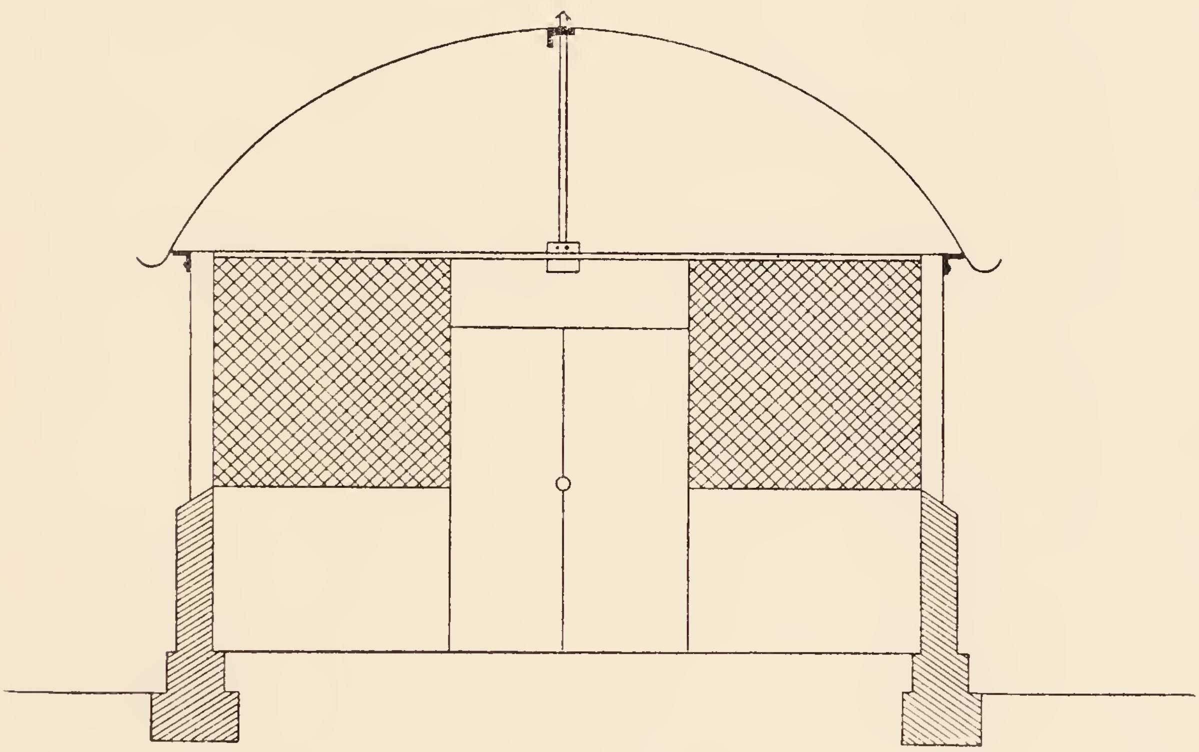


Fig. 96.

jail purposes, including cooking, amounting to about 15 or even 30 gallons per head, may be filtered, unless from a very contaminated source, without other attempt at purification. There is, however, always a certain risk, for the prisoners at times drink the water given them for washing in.

In selecting a water supply for a jail the purest source in the neighbourhood should be chosen after inspection, and every precaution taken to prevent extraneous pollution. If possible the supply should be taken from a large river. If from a river the precautions, already mentioned,

of taking it from the main current should be observed. If from a well the lining must be watertight, so as to prevent percolation from the upper stratum. The well should be protected by a parapet, be surrounded by a masonry platform, and a surface drain to convey the spill water into the ordinary surface channel of the jail, and prevent it from soaking into the ground. The well should be covered and the distribution, if possible, effected by pump and pipes. If a bucket and winch is used for raising the water, mechanical means should be used for emptying the bucket at a sufficient height above the well. If possible arrangements should be made to convey the water to the filter and boiler without having recourse to manual labour for this purpose, and it is desirable also that the filter and boiler should be at such a height as to allow the water being distributed by pipes to the place where it is used. If, however, the water has to be carried about in receptacles, these should always be covered, and they at the same time should be scrupulously clean.

Latrines.—The use of latrines by prisoners is usually arranged in parades in the early morning, and before and after each meal, five minutes or more being allowed for each prisoner. Each section or enclosure, or separate barracks has a separate latrine, which is constructed on similar lines to the iron sheds used as dormitories, *i.e.*, with angle iron supports, a curved roof, and a low wall on each side with entrance and exit. The latrine or shed is divided into separate compartments by low screens of corrugated iron, and in every compartment are two gumlahs or basins on the floor line, one in front of the other, with foot rests at the sides. This arrangement is to allow the user to squat, and at the same time to keep the solids and liquids separate. The receptacles which receive the solids should contain a layer of dry earth or ashes, of at least one inch in thickness, and every prisoner after he has used the receptacle is expected to cover his dejecta with a scoopful of

dry earth obtained from a small box, furnished with a wooden or iron scoop and placed in each compartment, or between every two. The earth has to be dried and sifted, and should be garden mould. The vessels to

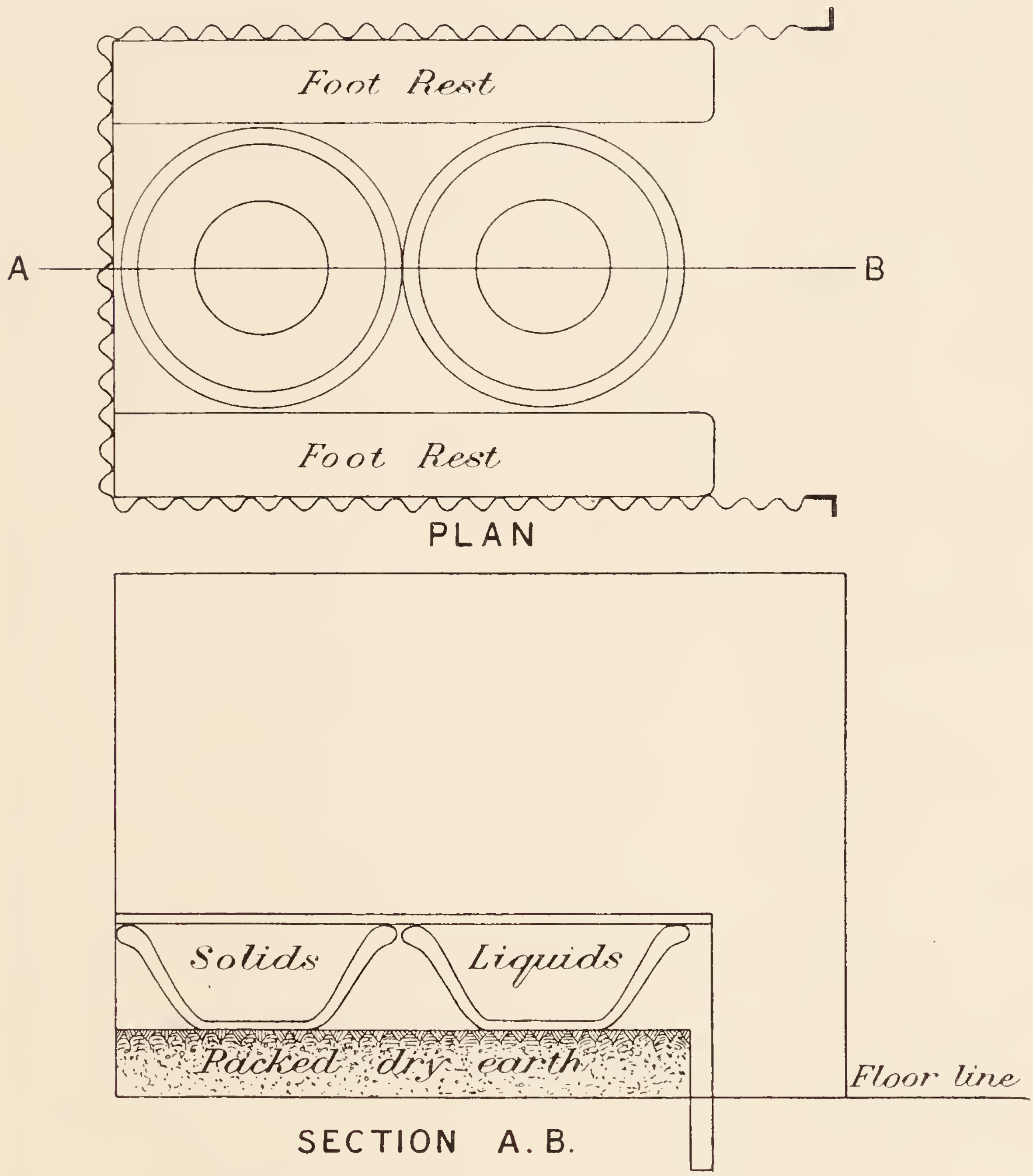


FIG. 97.

receive the urine have placed in them a small quantity of water, about one third the amount they will contain, in order to prevent them from becoming offensive.

The arrangement of the vessels on a foundation of packed dry earth, and of the foot-rests is shown in figures 97. For cleanliness and absorption of pollution

the floor under the gumlahs or vessels, and in the alley-ways, should consist of brick on edge, having a layer of not less than 4 inches of well packed dry earth placed over it. In addition to this the floor space, under the gumlahs requires a liberal sprinkling of loose dry earth, in order that any excrement falling outside the gumlahs may be at once absorbed. This loose layer is renewed daily, the old being put in the gumlahs with the solids and sent to the trenches. There should be one compartment for every six prisoners. There should also be attached to the latrine, but in a separate enclosure, a well raised ablution platform, draining into a receptacle which can be removed and carried away when filled. The ablution platform contains an ablution tub in each compartment into which it is divided, one compartment being generally found sufficient for every four seats in the latrine. An iron tub may be used having iron foot plates attached to the rim upon which the user squats. There should be a store house for the storing of dry earth, which has been pulverized and screened. The quantity required should be calculated at the rate of from 3 to 5 lbs., each prisoner per day. As it is impossible to prepare the dry earth during the rains a sufficient quantity should be stored during the dry weather to last for the whole rainy season. Garden earth is the best, gravel or sand is useless. The dust refuse of jute mills in Bengal is found to be excellent.

For prisons where labour is cheap and supervision good, the dry earth system is most successful. But if from lack of attention to detail and inadequate supervision moisture gains access to the latrines, either from rain or flood water, or from washings or spillings of urine, or there is neglect of cleansing the gumlahs or vessels, or omission of the regular use of dry earth in quantity and quality sufficient to secure perfect absorption and deodorization of the excrement, or of regular renewal of the earthen floors; then the system breaks down, and the dry earth latrine becomes a nuisance.

Collection and Disposal of Excreta.—After the parade the conservancy gang cover up all solid excreta with a thick layer of earth, but should use no disinfectants, and remove both the vessels containing the solid excreta and the vessels containing the urine to the depot, preparatory to trenching. The excreta are here dealt with in different ways in different jails; in some the utensils are put into trucks and removed by rail to the trenching grounds; in others the matter is carried by carts and pails to the trenching ground. In many Indian jails Donaldson's ejector is used. This consists of a cast iron pipe, 8 inches in diameter, having a hopper at one end. In the pipe is suspended on suitable bearings at both ends, a worm wheel of the conveyor type, which almost fills the diameter. This contrivance is built into the main wall of a jail, at a place convenient on the inside for the collection of the material, and on the outside to the jail garden. At the hopper or inside end is a crank handle for turning the worm, which is done by the conservancy gang. The operation is as follows: The excreta gumlahs are taken over from the latrines to the ejector and, with a liberal addition of dry earth, emptied into it one by one until the hopper is full. The worm is then turned by the handle, and has the effect of mixing up the dry earth and the excreta, as well as propelling it forward through the pipe and, consequently, through the outer wall of jail. On the outside of the jail the material is now in the form of poudrette, and drops into a utensil which, when full, is carried away and trenched. This process continues until the whole of the excreta of the various latrines of the jail has been disposed of.

After the solids are thus disposed of the liquids are also passed through the pipe, and whatever refuse there is from the food is also passed through and trenched in the same manner.

The advantages of the system are both sanitary and disciplinary. The Donaldson's ejector compels the treatment of the excreta of a jail in detail, and it is only in

detail that the dry earth system can be successfully carried out on a large scale in an institution, such as a jail, without offence. When a cart is used for removal of the excreta from the jail no intimate mixture of the dry earth with the excreta can be effected, and there is always the chance of improper trenching, the contents of the cart being dumped in one place to save trouble.

The use of a jail cart to convey the excreta outside the jail is not only offensive from the pollution of the air which it causes, but is objectionable in that there is always risk of the jail roads getting polluted from possible droppings of the material from the cart. From the disciplinary point of view a jail cart for this purpose often affords a ready means of introducing and conveying out contraband of all kinds, the warders declining to search the contents of the cart or the persons of the conservancy gangs.

The trenching ground or garden, having been properly drained so that it will not become water-logged with either storm or flood water, should be divided into plots of about 60 feet by 150 feet, and one plot should be regularly and systematically trenched before another is commenced. The trench to be used should be dug the day before to be in readiness. They vary in size in different jails ; some are made of 1 foot deep and 1 foot wide, and 18 inches apart ; others are made only 9 inches deep, 15 inches wide, and 6 inches apart. In both kinds 3 inches of pugged material is placed, and the earth dug out is then returned to fill up the trench. The urine and latrine ablution water is also trenched, but in separate trenches ; so also is all refuse, except ordinary sweepings and dry vegetable matter, which is generally placed in a manure pit at some distance from the jail.

The urine thoroughly diluted with two-thirds water is found useful for watering grass plots within and without the jail.

The actual area required to bury the excreta of a hundred persons is 6 square feet per day, which, with

two trenchings per annum, would amount to one acre of cultivable garden for 1,000 persons. These figures are governed by the condition of soil and climate of the particular locality where the trenching is carried on. If it is a sandy and stony soil, naturally the trenching would have to be spread over a larger area than is given here. In the particular locality where this estimate covered requirements the soil was a very rich loam, and the climatic conditions were good except for about three months in the year, when the rainfall was heavy and interfered with the process of absorption. At the end of three months the trenched part can be ploughed or hoed and put into cultivation. If it is cultivated earlier there is a risk of injury to the crops. In Bengal, moolies or country radish, which grow well in a rich soil and are rich in salts, are generally first cultivated; these are followed by a coarse crop, such as sag, and brinjal or the egg plant, and later followed by vegetables of various kinds. The coarser crops are generally planted at the beginning of the hot weather, and are continued until October. In this month Sutton's seeds from England comprising cabbages of various kinds, beetroot, kuol-kol, cauliflower, peas, beans, raddish, celery, and lettuce, are planted first in prepared boxes; then in November bedded out into nursery beds on a part of the garden which has not been trenched for a year or two years before, and has been under cultivation for that time. These nursery beds are previously manured with carefully prepared leaf mould, which has been matured by having been kept in covered pits for a year or two. When the plantings are strong enough to be moved, they are placed in specially prepared plots of the garden and carefully watered. A regular rotation of crops is thus maintained.

Prisoners Suffering from Infectious Disease. — In the event of a prisoner being attacked with an infectious disease, he should be at once removed to the hut or shed provided outside the jail, and the room, bedding,

and effects thoroughly disinfected and cleansed. In the case of cholera, boiled water only should be supplied to the prisoners if it has not been supplied before.

Disposal of Excreta of Prisoners in Hospital.—For the disposal of the excreta of prisoners in hospital suffering from bowel complaints, cholera, dysentery, or enteric fever, the practice usually followed is to cover the stool with quicklime or other disinfectant, and then remove to an incinerator within the hospital premises, and boil,

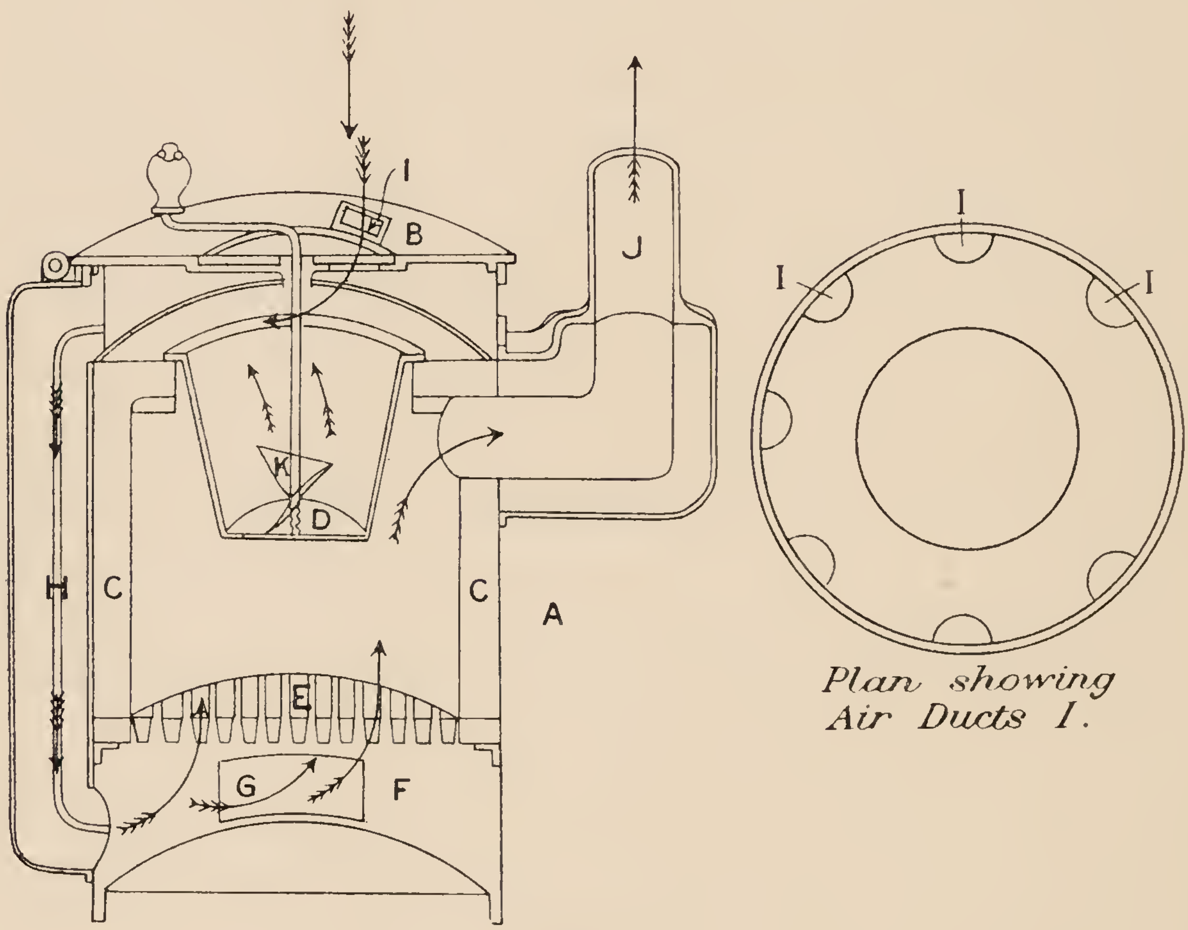


Fig. 98.

or mix with refuse and burn. An ingenious destructor for hospital use is the Donaldson destructor, designed to consume the infectious dejecta of patients, in which any offensive fumes formed are carried into the furnace and destroyed. Such an apparatus can be placed in the verandah of the hospital, or in any suitable place outside the hospital without causing offence when in operation. The woodcut represents a longitudinal section showing the interior.

A is an upright cylinder having a lid B, a firebrick lining C, which forms the sides of the furnace and upon which is suspended the metal pan D. E is the fire grate, F the ash-pit which has a door G, for the removal of ashes. H is an air pipe communicating between the pan and ash-pit. I is the inlet in the lid B, for the air required for the furnace. J is the exit for the products of combustion. This may be prolonged to any height by placing over it a stove pipe. K is a stirrer for turning over the contents of the pan D. It is fixed loosely in the lid B, so that it can be drawn upwards when the lid is opened, and descend into the contents of the pan D when closed.

To Work the Destructor.—Draw up the stirrer K as far as it will go, raise the lid B, remove the pan D, fill the furnace with coal and light up. Meanwhile, fill the pan with dejecta, place it in position and close the lid B, also close the ash-pit door G. The furnace can now only draw its air through the opening I, thus creating a strong indraught as shown by the arrows. This opening serves also as a peep-hole through which the contents of the pan may be seen at any time during the process, and because of this *indraught* the contents can be vigorously stirred and observed until consumed without raising the slightest malodour.

This operation can be repeated as required, taking care at the end of each operation to replenish the fire before commencing, because it is obvious that any interruption of the air current during the process means stench through the diffusion of the gases into the surrounding atmosphere instead of directing them into the furnace to be burnt. The ash-pit door G must remain closed until the dejecta has been consumed.

Methods Adopted to Gauge General Health of Prisoners.—The weighing of prisoners is employed as an index of the health condition of each prisoner. The weighing is generally carried out once a fortnight, and if a prisoner is found to lose in that time 4 lbs. he is sent to the

medical officer to be examined as to his state of health. Methods are devised occasionally by ingenious prisoners to increase their weight at one time and reduce it at another, so that the differences between two weighings are over 4 lbs. A favourite method to effect this is the drinking of large quantities of water before the first weighing and the abstention from water and eating less before the second weighing. By this means considerable differences in weight will be manifested. The medical officer will, however, soon learn to discriminate such artificial causes showing a sudden rise in weight on one occasion with a sudden fall on the next, from other causes affecting the average weight of the prisoner in question. If the fortnightly weighments indicate that an unusual proportion of the healthy prisoners have lost weight, a more nutritive diet must be substituted and more animal food issued until the loss in weight is recovered. Lighter work may also be ordered at the discretion of the medical officer.

CHAPTER XIV.

COMMUNICABLE DISEASES.

Classification of Communicable Diseases according to Transmissibility.—Communicable diseases may be directly transmissible from person to person or from animal to animal, indirectly transmissible or both directly and indirectly transmissible. Advances in the study and elucidation of the modes of transmission of these diseases tend more and more to diminish the number of diseases directly transmissible. Smallpox is perhaps the best example of a disease transmitted directly from person to person, but it is by no means proven that this is its only mode. Scarlet fever and diphtheria were at one time believed to belong to this class, now it is known they have also indirect modes of transmission. Malaria is a typical example of indirect transmission. It spreads only by the agency of the anopheles mosquito. Many of the diseases associated with animal parasites belong to the same class of indirect transmissibility. Most communicable diseases, especially of the epidemic type, are both directly and indirectly transmissible; for instance, cholera, which is most frequently conveyed by indirect infection may, under certain conditions, spread by direct transmission. Enteric fever is even more typical of this class than cholera. Plague in its pneumonic form is directly transmissible, while in its bubonic form its transmission is mostly indirect. Pandemic diseases possess endemic centres or homes from which they are rarely absent. Thus for cholera, one of its homes is the Gangetic delta; for plague, there is the endemic

centre of Yunnan; and for influenza, it is believed to be endemically prevalent in some parts of the Russian empire.

Different Modes of Manifestation of Communicable Diseases.—Communicable diseases may manifest themselves in a sporadic, endemic, epidemic, or pandemic form. When they attach themselves more or less to a locality they are said to be endemic. When they attain a high degree of prevalence in a locality where they are newly imported or where they are endemic, they are said to be epidemic. Epidemicity and endemicity differ in this latter case only in degree of prevalence. Pandemic applies to epidemic diseases, which not only attack several new localities but spread over many countries, and possibly over the greater part of the globe. The term is usually applied to cholera, plague and influenza. Sporadic is a term used to represent a few cases of a communicable disease, occurring singly or in groups in different parts of a locality, and apparently unconnected. They may crop up without any subsequent special spread of the disease, or they may be the precursors either of an epidemic or of the ordinary endemic prevalence of the season. It is difficult at times to differentiate between epidemic, endemic and sporadic, and to define exactly when the one merges into the other, especially when reporting weekly on a disease such as cholera. There is no difficulty outside the endemic area, but within that area there is not the same sharply defined limits between sporadic and epidemic. Thus thirty to fifty deaths a week from cholera in a non-endemic area would be considered to be an epidemic state of the disease, while in an endemic area such a number might readily be viewed as sporadic when compared with the much higher ordinary endemic weekly returns which are annually recorded, and which, in turn, may merge gradually or suddenly into returns in which there can be no question as to the disease being epidemic. For returns of this kind, which are

generally made up for international purposes, it is better to abolish such terms as epidemic, endemic and sporadic, and to simply give the number of cases or deaths for the week with the corresponding figures for the preceding five years. This arrangement prevents much misunderstanding, for it does seem anomalous to those living outside an endemic area to see marked against a return showing perhaps 150 or 200 deaths from cholera that the disease is sporadic. By those however, residing, in the endemic area, and where the figures are viewed from a different standpoint, it can be easily recognized that at each stage there may be hesitation into which category the disease at the particular time should be placed.

Some communicable diseases are more prone to the epidemic form than others, although at times and places they show themselves in a more or less endemic form. Similarly diseases which manifest themselves generally in an endemic form may occasionally become epidemic.

Epidemic Diseases.—There are circumstances under which nearly all communicable diseases may become epidemic, but as a rule the term epidemic is applied to those diseases which have a tendency to spread rapidly, and to invade more than one locality. Of diseases occurring in the Tropics which may be classed as epidemic smallpox, cholera, plague, yellow fever, and sleeping sickness are the chief, to which may be added dengue, relapsing fever, pneumonia and influenza. Of these, yellow fever and sleeping sickness, if the present theories as to their mode of spread are accurate, are limited in their range of extension by the geographical boundaries of the *Stegomyia fasciata* mosquito and of the *Glossina palpalis* tsetse fly, the respective carriers of these two diseases. The geographical distribution of both these carriers is a wide one, and within this wide limit there may occur very severe epidemics.

Endemic Diseases.—Under the endemic class of diseases are usually included malaria, Mediterranean fever, dysentery, leprosy, enteric fever, tuberculosis, kala-azar, and the

entozoal diseases. They may be, and often are, as destructive as those that come under the designation of epidemic, but by their very frequent appearance in the localities in which they are endemic they do not, unless prevailing in somewhat unusual proportions which force attention to them, cause the same amount of alarm, and are often taken as a few of the ills which man is heir to.

The Nature of Infection.—Although the actual *materies morbi* has not been recognised in small-pox, yellow fever, dengue, and some other infectious diseases, yet, in the majority of communicable diseases, a specific micro-organism has been discovered capable of living a parasitic existence for a time in the human body. There is every reason to assume that in those diseases in which the specific organism has not been discovered, it nevertheless exists and is unrecognisable because of defective methods employed for its detection. Generally the infections seem to act as ferments in the body, their products causing disturbance of the system by chemical and physiological means rather than by mechanical obstruction, but there are exceptions to this as in the case of filariasis.

The infection may be divided into two great classes, viz., those belonging to the vegetable and those to the animal kingdom. The infections from the vegetable kingdom are derived from the group of schizomycetes or fission fungi which consist of microscopic organisms of protoplasm in a cellular membrane. They are destitute of chlorophyl, and multiply by fission. They are commonly designated bacteria. The infections from the animal kingdom are divisable into several classes of which the protozoa and helminthes are the most important. The protozoa are the lowest and simplest division of the animal kingdom and are unicellular creatures either single or in groups. The microbes of plague, cholera and typhoid fever are examples of schizomycetes. The diseases they produce belong to the bacterial group of infections. The sporozoa of malaria, the Leishman-Donovan body of kala-azar and the

trypanosome of sleeping sickness are examples of protozoa. The diseases caused by them are due to protozoal infections. On the other hand filariasis, ankylostomiasis and bilharzia owe their origin to helminthic infections.

Of infectious diseases in man of which the causal agent is known, the majority are due to bacteria; next in order are those caused by helminthes and lastly, those by protozoa. The trend of discovery however is to add to the list of protozoal diseases rather than to the bacterial.

There is another group of animal parasites which affect men, viz., the arthopoda, but they are of small importance.

Limitations affecting the Infections due to Animal Parasites.—The diseases due to the invasion of animal parasites are generally more limited in their geographical distribution than those due to vegetable micro-organisms and are generally in the endemic group. The reason is not far to seek. The animal parasite if it multiplies directly without an intermediate host is often affected by temperature. Such is the case with the *Ankylostomum duodenale*, the eggs of which develop in tropical regions, but are destroyed in cold regions. Transported from warm latitudes it is only under special conditions in mines and underground excavations in temperate climes when the temperature approaches that of a tropical or subtropical character that ankylostomiasis flourishes outside its endemic area. When again the parasite causing the disease is dependent on some other host than man to complete its life cycle, and if that other host does not exist in the locality outside the endemic area to which the infected man travels it is impossible for the disease to spread.

A man infected with the malarial parasite cannot spread the disease unless the anopheles mosquito is present to extract the parasite from his blood and carry on the development of the cycle. Similarly, it would seem that the same restrictions obtain in regard to sleeping sickness, and its dependence on the relationship of the trypanosome to the tsetse fly, *Glossina palpalis*.

The Infections due to Bacteria of wider Extension.—No such restrictions hinder the spread of diseases due to bacteria, and accordingly they form the major portion of those diseases classed as epidemic. There are restrictions to the development of bacteria, but they are not those connected with alternation of generation and change of host for their life cycle.

Bacteria are seldom purely parasitic, most of them are facultative, and are capable of leading a saprophytic existence. They can live outside the human body, they can multiply within certain limits so long as they obtain a supply of organic matter, and are not a prey to other microbes; and they can, in many instances, multiply in some of the lower animals. On the other hand, they are sensitive to many of the agencies around them, which prevent them from attaining those enormous numbers which their rapid development might otherwise ensure for them.

Modes of Bacterial Infection.—Discharged in large numbers from man or the lower animals, in which they are parasitic, they might infect others at once, by direct contact gaining access through the respiratory passages, the alimentary canal or the skin, or they may attach themselves to soiled articles, and be thus transported independently of the sick man or animal, and by their capacity of being able to multiply outside the human body they can contaminate food, drink or air, and be conveyed by them once more to the human body, or they may reach their host by infected insects. The variety of unseen methods by which microbes can reach the human body, often render the epidemic diseases caused by them very difficult to combat. It is essential for fair success under all conditions to at least know the principal disseminating media, and for full success to know them all, otherwise the preventive measures may not be directed to the actual producers of the disease. Thus when cholera was believed to be spread through the air, methods of prevention were adopted which

affected only in a very indirect way the agent spreading the disease. It was a regular practice in India, at one time, when cholera broke out in a regiment, for the disease to be attributed to particular winds carrying the cholera poison to the camp, and on this theory the regiment would change its camp several times, in order to remove itself from the influence of the wind. It was called cholera dodging. This method of prevention could not be applied to a civil population, whose residences were of a more permanent kind. The method, when followed by good results, strengthened the theory of aerial dissemination. It is now known that the successful results were due to leaving behind in the camp an infected water supply and, probably, infected latrines, where by soiling of boots and then of the hands, and the agency of flies swarming in the latrines, food and drink were liable to contamination with the cholera infection.

Some epidemic diseases, while capable of extension by several modes of dissemination, show a preference for a particular vehicle as a means of conveyance. Thus while it is necessary to guard against all known means of conveyance, special precautions have to be taken regarding some particular one. Thus it comes to be, that though the methods of dealing with epidemics due to bacteria generally involve procedure on the same lines, up to a certain point they may then diverge considerably.

Methods of Prevention.—Thus isolation of the sick from the healthy, disinfection of the discharges of infected patients, disinfection of the clothes and bedding of the sick as well as of the infected premises, are preventive measures common to all epidemic diseases. These measures have often to be supplemented by others of a different kind, for in some diseases they are not the most important measures, except in those instances when the cases have been imported, and have not arisen in the locality itself. In an outbreak of cholera, for instance, they would not be sufficient to prevent the disease from spreading. Isolation would, under these circumstances,

prove to be a failure. Cholera is known to spread chiefly by means of contaminated water, milk and food. It is a matter of drinking or eating cholera, and the most important measure is the stoppage of the supply of contaminated drinking water, milk or food, and until it is ascertained which of these is causing the disease the healthy should drink no water or milk that has not been boiled, and eat no uncooked vegetables. Moreover, as flies are apt to carry the infection to food and drink, measures should be taken to prevent flies coming in contact with discharges which have not been disinfected, and to protect all food and drink from contamination by efficient screens. A further protection to the individual, when the source of infection is not ascertained, is inoculation against cholera. The effects of this inoculation last about a couple of years.

Isolation of the sick with disinfection is of great value in small-pox, and there is no need to take special precautions with the water supply or food supply further than to prevent the portions of food, water or milk left by the patient being partaken of by others, or the dishes used again until disinfected. The food and drink need to be screened against flies. The patient requires also to be protected by a mosquito net against flies, otherwise there is danger of flies spreading the disease. Hospitals should also have their doors and windows protected with mosquito netting, which prevents flies from gaining access to the hospital wards. Flies constitute one of the nuisances connected with small-pox hospitals, and they are not only a nuisance to patients and the neighbourhood, but they are likely carriers of infection. The aeral spread of small-pox is probably, in most instances, to be explained by the *role* which the fly plays in disseminating infection. The most powerful measure, far more important than isolation in hospital, is protection of healthy persons by vaccination and revaccination.

Isolation in hospital cannot always be carried out,

even in such a disease as small-pox, especially in Tropical countries. Such a measure is objected to, and when the objection cannot be overcome, the only measure of value is vaccination of the members of the household, and of the households of neighbouring houses. This often proves an effective barrier against the spread of the disease. The only isolation that will be followed is keeping the patient within his house. The isolation of all cases of plague, and disinfection of sputum and discharges, are measures of the greatest importance in the early stage of an outbreak of plague, and are almost sure to meet with success if the disease is of the pneumonic type, and the rats of the locality are not infected, but once these animals become infected isolation alone will not affect the purpose in view, owing to the fact that the rats become the chief disseminators of the disease, and measures have to be devised for the destruction of these animals. It has been established also that fleas play a part in the dissemination of plague, they spread infection from rat to rat, and probably in some cases spread the disease from rat to man.

The chief additional measures against plague are accordingly destruction of rats and fleas, disinfection and inoculation with Haffkine's prophylactic. As in the bubonic form it is a house disease, the house or hut should be evacuated until these measures have been carried out.

Rats can be destroyed by poisoning them with Danyz's virus, if it can be maintained at a high strength. This, however, is difficult, and the virus not infrequently weakens to such a degree as to be useless. The method of exaltation consists in injecting a portion of the attenuated cultures into the peritoneum of a rat, and removing the peritoneal effusion in from twelve to twenty-four hours, allowing the fluid to stand in a sterile test tube from twelve to twenty-four hours for the purpose of aeration. Cultures from this tube are then made on agar, and fresh passages made. After a series of six to eight passages the virus becomes exalted,

when ordinary cultures are prepared on agar. Bouillon is poured into the agar tubes containing the fully grown cultures, and the whole is shaken up. The mixture is then poured into dishes, and pieces of stale, dried bread, about 1 cubic inch in size, are dipped into the emulsion; when dry, the pieces of bread are packed in a tin and distributed in the evening. The virus takes from eight to ten days to act, and should be laid down in infested localities daily.

Poisons such as arsenic, phosphorus, and strychnine, mixed with other substances, are also used for destroying rats. Care has to be taken that they are not distributed without warning. They should be laid at night when children have gone to bed, and domestic animals have been tied up, and those pieces remaining should be removed in the early morning. Fumigation with the Clayton apparatus is another method of destroying rats, together with vermin, in houses and drains. This is best effected by a portable Clayton disinfecting machine being taken to the house at which it is to be carried out. It disinfects the house, at the same time the sulphurous acid gas destroys the plague bacillus.

One of the most powerful weapons against plague is inoculation of the people with Haffkine's prophylactic. The dose for an adult is three milligrammes. The syringe should be sterilized by boiling in water, and the needles should be dipped after each injection into boiling oil. The forceps should also be boiled, and before each operation sterilized by heat. Should they be dropped on the ground, or for any reason laid on the table, they should be sterilized by heat before removing the cork of the bottle containing the prophylactic. The neck and cork of the bottle containing the prophylactic should be heated in the flame, to sterilize any dust on it before opening, and the cork should be removed only with sterilized forceps.

It is best to inoculate subcutaneously in the arm over the deltoid, and the part of the arm selected should be

first washed with soap and water, and then swabbed with carbolic oil.

As regards yellow fever, there is no preventive inoculation at present, the causal agent which is carried by the *Stegomyia fasciata* not having yet been discovered. Measures have to be directed to the destruction of the mosquito, to the fumigation of infected houses, and to the protection of infected persons from the bite of the mosquito. All the measures employed in connection with malaria and malarial patients should be instituted to combat yellow fever.

In each disease, general hygienic measures, which remove the physical conditions favourable for growth of the microbe giving rise to the disease, should be brought into requisition.

Immunization against disease by vaccination and inoculation is an important measure in the prevention of small-pox, cholera, plague and typhoid fever. The immunization is effected by the employment of a vaccine or prophylactic fixed in its strength, and while being protective is harmless to the individual or community. Inoculation against disease is a very old method of protection, and it was particularly employed against small-pox and plague.

The older methods of inoculation, whether for small-pox or plague, depended on the employment of crude material containing the living germs of the disease, and over these there was little or no control. Sometimes the material was efficacious and harmless, at other times it was dangerous. There was also risk of the method, while protecting the individual inoculated, spreading the disease to healthy persons. The discoveries of Jenner, Pasteur, and Haffkine have introduced new methods by which the material employed is fixed in strength, protective and harmless to the individual, does not spread the disease, and is fully under control.

Jenner's great discovery lay in the fact that he ascertained that the passage of the small-pox virus through

the cow fixed its properties in such a manner that the immunizing effects of the small-pox virus were retained, while its power of producing the disease was destroyed. The defects of inoculation with the small-pox virus consisted in the danger to the inoculated which sometimes attended the operation, and in the risk of infection which sometimes spread from the inoculated to other persons. Notwithstanding these disadvantages, inoculation was practised as the lesser evil, because in the majority of cases its effects were comparatively mild, and it conferred a very high protection.

There is a difference between the cholera and plague inoculations introduced by Haffkine. In cholera a living vaccine is employed ; in plague a devitalized or chemical vaccine is used. The cholera vaccine needs to be fixed in its strength in order that the microbe shall behave constantly in the same manner when injected alive into man. It was the non-recognition of this fundamental principle which led to Ferran's failure in Spain. He practised inoculation against cholera on the same principle as the old inoculations against small-pox. The crude microbe isolated from a cholera patient was employed without fixing its strength. In Haffkine's method of inoculation against cholera there are two vaccines. The cholera microbe is first fixed at a high stage of virulence by passing through animals, and is maintained at its high strength by the same process. It is necessary to mention that the cholera microbe requires air for its life, and accordingly in the process of passing it through a succession of animals it is necessary to alternate this procedure with aeration of the microbe for some hours, otherwise it will die. It is in this way that the strong vaccine is obtained. But as this vaccine when injected under the skin of animals is apt to produce a slough, an attenuated microbe is used as a first vaccine. The attenuation is attained by a prolonged aeration and exposure to a continuous high temperature.

The advantage derived from using a living vaccine is

that the immunity is higher and of longer duration. The disadvantage is that it has always to be prepared afresh by a bacteriologist, and, consequently, difficulties arise in its preparation and distribution over large and numerous areas, whereas a devitalized or chemical vaccine can be preserved for a considerable time, and sent out to great distances and administered by any physician who knows how to employ it aseptically.

Toussaint was the first to introduce chemical vaccines. He employed a vaccine of this kind against anthrax prepared from the heated defibrinated blood of dead animals. The method worked well as long as there were no spores in the blood. The heat to which the blood could be subjected without being coagulated—viz., 57° C.—would not destroy spores, so that if these were present, and animals were inoculated, the result was the death of the animals and the danger of spread of anthrax to other animals.

Many experiments were tried on similar lines by others with different kinds of microbes and on different animals, but the immunity obtained by such chemical vaccines was so short-lived that the methods could not be used for practical purposes, and so it happened that up to the time of the cholera inoculations inclusive all vaccinations were done with living vaccines.

Haffkine's prophylactic against plague, consists of old cultures of plague bacilli, rich in bacilli and their secretions, the bacilli having been killed by heat.

A suitable medium for obtaining such cultures is peptone broth, to which are added a few drops of butter or oil. The plague bacilli in this medium, when kept in a condition of perfect quietness, grows from the surface downward into the fluid in the form of stalactites, a formation which belongs to no other bacillus. Sir Almroth Wright's anti-typhoid prophylactic is based on similar principles. By the end of six weeks the culture is ripe for use, and its purity is ascertained by drawing off a small quantity and subjecting it to certain tests.

The culture is then heated at from 55° to 60° C. for twenty minutes, with the result that the microbe is devitalized. The prophylactic then becomes a chemical drug, with fixed properties, and can be used in measured doses like other drugs. The preliminary fixation of the biological and pathogenic properties of the microbe is, under such conditions, not an essential process, as in the case of cholera and small-pox, where living vaccines are introduced into the system.

Methods of Prevention for Diseases caused by Animal Parasites.—The preventive measures employed against the diseases caused by the animal parasites differ in some respects from those adopted for diseases due to the fission fungi or schizomycetes. The protozoic group represented by malaria and trypanosomiasis cannot have their infections conveyed at once either directly or indirectly from the sick to the healthy. The infection does not make its exit from the body in the discharges and does not leave the body unless removed by a suctorial insect. That insect in the case of malaria is the anopheles mosquito and in the case of sleeping sickness the *Glossina palpalis*. Isolation for malaria in the sense of segregation of the sick from the healthy, to prevent the healthy from becoming infected is not needed, but isolation in the sense of protection of the sick from the bites of anopheles is essential in order that the mosquito may not become infected, and afterwards infect healthy persons. This protection is given by placing the malarial patient under a mosquito net, or in a mosquito-proof room. There is no object in disinfecting the excreta, but the sporozoa inside the body are attacked by the administration of quinine, or Euquinine which has the advantage of being tasteless. Most of the preventive measures have no relation to the patient but are directed to the anopheles, the carriers of infection, against which healthy persons have to be protected. This protection is effected in several ways. One is to protect the interior of the house from mosquitoes by mosquito wire netting to the win-

dows and outer doors; another is to destroy any mosquitoes that have found access to the house, by fumigation or other means of destruction; a third is to destroy the larvæ in existing ponds, by treating them with a layer of kerosine or petroleum spread over their surface; and a fourth is to remove the nurseries and breeding-places of mosquitoes and the conditions which lead to the formation of these places, by introducing efficient drainage and conservancy, and by the establishment of a mosquito brigade, the coolies of which shall be regularly employed in the destruction of mosquitoes.

The helminthic group is a difficult class of communicable diseases to deal with, for the patient seldom comes under observation until the disease is well advanced, and in the meantime, if the conditions are favourable, he has formed a new centre for the extension of the disease. Although the majority of the group does not spread by direct infection and requires an intermediate host for the full development of the parasite causing the disease, yet few infected persons do not at some period or another discharge the ova or embryos of the parasite in the fæces or urine. It is therefore of the highest importance that the excreta should be thoroughly disinfected in order that the ova and embryos shall be destroyed. As this is generally unlikely to be adopted until too late in particular cases, the preventive measures lie in the provision of good latrines and a proper disposal of the sewage. In this way there is less opportunity of the ova or embryos reaching the soil or water, or vegetables, and then the host or intermediate host necessary for the development of the parasite. Boiling or filtering the water is another measure; thorough cooling of all foods and inspection of all meats are others. In the case of filariasis the destruction of mosquitoes will be a powerful sanitary measure in the lessening of the disease due to these parasites. In the case of bilharzia arrangements should be made that the dejecta do not reach water in order that the embryo or miracidium shall

23

have no opportunity of developing. Formalin 1 in 160 and chrysoidin 1 in 20,000, prevent the eggs from hatching.

Preventive measures against epidemic diseases are directed to protecting the locality against importation of the disease, against lodgment when imported, and against extension of the disease once it has gained a lodgment. The measures adopted, though involving much in common with the routine procedure for all epidemic diseases, will vary with the disease to be dealt with. The measures to prevent extension in a locality have already been dealt with. If the locality is not infected but threatened, attention has to be paid to the localities in which persons coming from infected districts reside. Sanitary districts have to be formed for the proper supervision and control of any cases of infection which may be imported. Immediately a case occurs measures must be taken for its isolation and removal from the house to a hospital, for the evacuation of the house until it is thoroughly disinfected and, in the Tropics, until the vermin are destroyed. Accurate diagnosis and familiarity with the nature of the infection, with the period of incubation, with the channels of infection as regards entrance to and exit from the body, with the modes of dissemination of the infection and with the methods by which they can be combated, are essential for success. On these data, as far as they are known at present, are based the international regulations of the Paris Convention of 1903, to prevent the importation of cholera, plague, and yellow fever. No other epidemic diseases have up to the present been the subject of international control. Yet, from a local point of view, there are other diseases which, though not so appalling in their mortality and rapidity of death as plague and cholera, are still so severe as to render it a matter of supreme importance that their importation and lodgment shall be prevented.

Prevention of importation depends largely on the

amount of information available regarding the presence of epidemic disease in neighbouring countries or in those which are connected by commercial relations. If that information is not forthcoming precautions are likely to be taken when too late, and when the disease has already been introduced. The signatories to the Paris Convention, recognizing this fact, have agreed to at once notify to each other the occurrence of cases of cholera, plague or yellow fever in their dominions, but more particularly the two former diseases. This is a very important advance in the direction of preventing the spread of such epidemics, and is as valuable to international hygiene as local notification of infective diseases is to local hygiene. The international notification puts the different Governments on the alert and gives them timely warning to take the necessary precautions both by sea and land, which shall as far as possible, consistently with the needs of commerce, prevent the importation and lodgment of the disease in their country.

For large seaports the Convention recommends that there be provided :—

(*a*) A properly organized port medical service and permanent medical supervision of the health conditions of crews and of the population of the port.

(*b*) Suitable accommodation for the isolation of the sick, and for keeping suspected persons under observation.

(*c*) Bacteriological laboratories and the buildings and plant necessary for efficient disinfection.

(*d*) A supply of drinking water of quality above suspicion at the disposal of the port, and a system of scavenging that offers every possible guarantee for the removal of excrement and refuse.

Equipped in this manner, the port authorities are at once able to meet an emergency and to set in motion the machinery as soon as information reaches them that disease has broken out in a country with which they have commercial relations. It is obvious that all ships coming from an infected port will not bring infection, and for

this reason such ships are classified into infected, suspected and healthy, in order that they may be treated differently according to the danger incurred by them.

An *infected ship* is one on which there is plague or cholera on arrival, or on which there has been one case or more of plague or cholera on board within seven days of arrival.

A *suspected ship* is one on which there have been cases of plague or cholera on board at the time of departure, or during the voyage, but no fresh case within seven days of arrival.

A *healthy ship* is one on which there has been no case of cholera or plague either before departure, or during the voyage, or on arrival.

All ships from an infected port are subjected to medical inspection, and the measures taken depend on the events that have occurred during the voyage. *Healthy ships* are at once given free *pratique*, but the passengers and crew are subjected to "surveillance" for five days from the date on which a ship left an infected port. The authorities may also insist on the disinfection of soiled linen, wearing apparel, and articles belonging to the crew and passengers which they may think there is a possibility of having become infected, and they may, when the ship is from a port infected with cholera, insist on the bilge water being disinfected and pumped out, and a supply of wholesome water substituted for that stored on board. In the case of a ship coming from an infected port, particularly a plague infected one, the authorities may subject it to a process intended to secure destruction of rats on board either before or after discharge of cargo, although it is added that this measure must not be resorted to as a general rule.

Suspected ships are treated with more care. The crew and passengers may be subjected to surveillance during a period which must not exceed five days reckoned from the arrival of the ship. The soiled linen and personal effects of the crew and passengers are disinfected ; the

parts of the ship which have been occupied by persons ill with cholera or plague, or that the sanitary authority regard as infected, shall be disinfected. In the case of cholera in a suspected ship the bilge water must be disinfected and pumped out, and the sanitary authority may order that a supply of wholesome drinking water be substituted for that stored on board; and in the case of plague the destruction of rats on board the suspected ship is recommended.

Infected ships are treated even more strictly. After medical inspection the sick are immediately disembarked and isolated. The other persons must also be disembarked, if possible, and, *in the case of cholera*, either be kept under observation,[1] or subjected to surveillance,[2] during a period which shall vary with the health conditions of the ship and the date of the last case, but which shall not exceed five days, reckoned from the arrival of the ship; in *the case of plague* they shall either be kept under observation during a period which shall not exceed five days, *and* which may or may not be followed by surveillance of not more than five days duration, or merely be subjected to surveillance during a period which shall not exceed ten days. The period shall date from the arrival of the ship. It rests with the sanitary authority of the port, after taking into consideration the date of the last case, the condition of the ship, and the local possibilities, to take that one of these measures which seems to them preferable. Soiled linen, wearing apparel, and articles belonging to the crew[3] and passengers which

---

[1] "Observation" means isolation of travellers either on board a ship or in a sanitary station before they obtain free pratique.

[2] "Surveillance" means that travellers are not isolated; they receive free pratique immediately, but the authorities of the several places whither they are bound are informed of their coming and they are subjected to medical examination with a view to ascertaining their state of health.

[3] "Crew" means persons forming or having formed part of the crew or staff of the ship, and includes stewards, waiters, cafedji, &c.

are, in the opinion of the sanitary authority, infected shall be disinfected. The parts of the ship that have been occupied by persons ill with cholera or plague, or that in the opinion of the sanitary authority are infected, must be disinfected. In the case of cholera the bilge water must be disinfected and pumped out, and the sanitary authority may order that a supply of wholesome drinking water be substituted for that stored on board. In the case of plague the rats on board must be destroyed either before or after discharge of cargo, but within a maximum time of forty-eight hours.

When rats on a *healthy ship* have been shown by bacteriological examination to have plague, or when unusual mortality among these rodents has been observed, suspected to be due to plague, measures must be adopted after medical inspection and examination to destroy the rats, either before or after discharge of cargo, as quickly as possible, and in any case within a maximum period of forty-eight hours.

In addition to the precautions at the port of arrival, certain methods are enjoined on the authorities at the infected ports on the departure of vessels. These are the taking of effectual measures (1) to secure medical inspection of the passengers and crew; (2) to prevent the exportation of such merchandise or articles of any sort as the authorities may regard as infected, and which have not previously been disinfected on shore under the supervision of a doctor appointed by the public authority; (3) in the case of the plague to prevent rats gaining access to ships; and (4) in the case of cholera to see that drinking water taken on board is wholesome.

For prevention of importation by land the Convention no longer places any dependence on land quarantine, which it abolishes so far as Europe is concerned. States however retain the right to close their frontier, or part of it, in case of need. Governments have also the right reserved to them of taking special measures in regard to certain classes of persons, notably gipsies, vagrants,

emigrants, and persons travelling or crossing the frontier in bands. For ordinary travellers, they are to be subjected to medical inspection, and only the sick or ailing detained. Travellers from an infected place on arrival at their destination should be subjected to surveillance for a period not to exceed ten days in the case of plague, and five days in the case of cholera.

For Europe and other countries advanced in sanitary organization, these regulations secure a very considerable degree of protection, but for tropical countries with their different conditions, and often with no proper sanitary organization, certain modifications are desirable in order to prevent the importation of plague by land or sea. These are, that native passengers from an infected point should at the time of embarkation and inspection by the medical officer of the port produce a certificate of having been inoculated at least a week previously; and that natives from an infected area should not be admitted into healthy areas without passports indicating that they have been inoculated. On the great highways of commerce through the Tropics much has been recently done, especially in British ports, to conform more or less to recommendations of the Convention. In ports at which emigrants and large numbers of coolies are received, strict quarantine for fourteen days is usually imposed at a quarantine station, and it is not until the lapse of this period, and after the clothes and effects of the coolies have been disinfected and they themselves have been bathed, that they are permitted to proceed inland.

Disinfection.—No disinfection is complete which does not destroy the agents of infection. Disinfectants are bactericides; antiseptics arrest or impede the growth of microbes without destroying their vitality; deodorants oxidize and destroy or mask the effluvia which are the frequent by-products of bacterial action.

Disinfection may be effected in various ways. The simplest method is exposure to sun and air, which will in time destroy the microbes. In some out-of-the-way

places, exposure to the sun and air may be the only method available, and if the infected material is well spread out, so that the rays of the tropical sun penetrate it, the disinfection is likely to be complete. All the surfaces of the article to be disinfected will have in turn to be exposed to the direct rays of the sun. The method, however, as regards thick woollen material and unopened bedding, especially if much saturated, is somewhat uncertain as regards the thoroughness of the disinfection process. Fortunately, such articles are seldom to be met with in the Tropics in the case of natives, except perhaps a blanket. Infection may also be removed mechanically by stripping and scraping of walls, the material thus collected being burnt, or it may be removed by washing. The usual agents employed for disinfection are (1) heat; (2) chemicals.

The heat may be applied by burning the infected articles; this is easiest and best if they are of small value, which is generally the case as regards clothing, bedding, and the effects of natives in the Tropics, or it may be applied by boiling the infected articles if they are washable, or by exposure to hot air or steam. It is often cheaper to burn the scanty clothing, mats, and other suspected articles, and compensate for the loss, than to subject them to some chemical disinfection. The same remarks also often apply to the treatment of an infected hut where cholera, plague, or other dangerous infectious disease has broken out, and the disease is localized and still sporadic. Prompt burning down of the hut, after the patient has been isolated or has died, prevents any further spread of the disease. In the case of plague, a suitable fence should be put at a few yards distance round the hut before it is set on fire, so that all rats belonging to the hut may be destroyed and not allowed to escape.

Heated air for the disinfection of clothes and bedding is slow in its action, and has very little penetrating effect, so that the microbes may be destroyed on the surface of

a thick material, but not on the inner layers. Hot air at a temperature of 220° will destroy the spores of bacilli in four hours, which steam at a temperature of 212° or boiling will destroy in five minutes. Heated air may, however, be the only means at command, and in that case blankets and bulky materials of the kind should be spread out as much as possible, for if they are folded up into many layers, the heat within these layers is unlikely to reach the proper temperature, even though the outer may be raised to a point that scorches them.

Long exposure to a temperature ranging between 230° and 250° is necessary for disinfection by hot, dry air; four, six, or eight hours being usually assigned, according to the bulkiness of the articles.

Steam has a much more penetrating and rapid effect, whether employed in the form of saturated steam, which is at a temperature slightly above that at which it is generated, or superheated steam at a temperature several degrees above that at which it is generated, or current saturated steam in which there is no obstacle to the escape of the steam generated.

The advantages of current saturated steam disinfectors are, that they can be made of light material, their construction is easy, there is no need of a strong and heavy boiler, and their initial cost and management are less expensive.

High-pressure disinfectors are represented by those made by Manlove Alliott and by Goddard, Massey and Warner.

Washington Lyon's apparatus, as made by Manlove Alliott, is of any shape, with doors on both ends, has 30 lb. per square inch in the jacket, and 20 lb. in the chamber, so that the steam in the chamber is not superheated. The latest forms include Alliott and Paton's vacuum apparatus to obtain better penetration. The penetration is greater if the pressure in the chamber is intermittent, ten to twelve minutes is sufficient, the steam is allowed to escape, and the articles are dried by current hot air. The appara-

tus is usually so placed that one end of the disinfector opens into the room receiving the infected articles, and the other end opens into another room which receives from the disinfector the disinfected articles. By this arrangement, and by opening only one of the doors at one of the ends of the disinfector at a time, there is no possibility of re-infecting the articles once they have been disinfected, the only communication between the two rooms being through the disinfector. The Goddard, Massey and Warner apparatus is square, double-jacketed, steam not superheated, but is at 20 lb. pressure in the chamber and the jacket. The drying is effected by a current of hot air drawn through the chamber. Hot air is also drawn through for two or three minutes before the steam is turned on.

Low-pressure systems are represented by Recks and Threshes' apparatus.

As regards disinfection by chemicals, the chemicals employed in solution are usually corrosive sublimate, cyllin, izal, kerol, carbolic acid or acids. Corrosive sublimate 1 in 1,000, cyllin and kerol 1 in 200, izal 1 in 100, and carbolic acid 1 in 20, are the usual strengths. In preparing these dilutions, the volume of inert matter with which the disinfectant has to be mixed must be taken into account. Corrosive sublimate solution, however, is very poisonous, acts on metals, is easily thrown out of solution by alkalies and organic matter, is acted on by oxides, sulphur and sulphuretted hydrogen, and is apt to lose its efficiency when mixed with discharges, sputum, and the like, by forming a coating of albuminate of mercury, which protects the micro-organisms to be destroyed from the action of the corrosive sublimate. To prevent this there should be added to the corrosive sublimate solution when used for other purposes than steeping clothes and utensils in the solution, or disinfecting the hands, a slight excess of hydrochloric acid, and some chloride of ammonium or soda, which assists in disintegrating organic material.

The usual standard solution consists of :—

Perchloride of mercury	21 oz.
Chloride of sodium	15 oz.
Hydrochloric acid	100 oz.
Aniline dye (blue)	1 oz.
Water	340 oz.

5 oz. of this solution mixed in a gallon of water gives a strength of 1 in 725. The aniline dye is added to the solution to prevent accidents, by the solution being mistaken for water. Cyllin and kerol are excellent disinfectants, form fine permanent emulsions with water, are about sixteen times as efficient as carbolic acid when tested on bacterial cultures, and are much less toxic than the latter, nor do they act on metals. They are also compatible with soap, which is not the case with perchloride of mercury, but must not be mixed with acids; the material should be neutral or alkaline, or only slightly acid, which is generally the case in all fermenting or putrifying substances. The solutions, as sold, are purposely made very alkaline, in order to prevent decomposition in coming into contact with an acid. Sulphuric acid 1 in 250, to which permanganate of potash of about the same strength has been added, is useful for washing out passages, courtyards, and surface drains.

For fumigation purposes three processes may be employed :—

(1) Fumigation by sulphuric anhydride and sulphurous acid gas.

(2) Fumigation by formaldehyde.

(3) Fumigation by chlorine gas.

Fumigation by sulphur is a very ancient practice, and one which has much in its favour. Gaseous disinfection, if effective, is more easily and uniformly applied than other forms of disinfection. There is no necessity for removing any of the articles from the infected hut or house, as everything can be disinfected by the same fumigation. It has been found, however, that the mere burning of sulphur in the open air of a room, though

rendering the air irrespirable for human beings, yet does not effect that complete disinfection or destruction of infectious material which assures safety. It is for this reason that the ordinary operations of disinfection usually consist first in fumigating the infected room, then removing the clothes, bedding, curtains, &c., to a disinfecting station, to be there disinfected by steam or heat, and finally washing with a chemical disinfectant the walls, floors, and furniture, in addition to scraping the wall and burning paper and plaster thus scraped off. No reliance can be placed on fumigation for the efficient disinfection of everything, when the fumes are generated by burning sulphur in the open air. About 3 or 4 per cent. of sulphurous acid with one-tenth of a milligramme of sulphuric anhydride is the most that is given off by the burning sulphur. The case, however, is different when the sulphur is burnt in a Clayton apparatus. In this, the sulphur burning in a furnace supplied with air by an induced draught, owing to the intensity of the heat produced, can generate not only sulphurous acid, but larger quantities of sulphuric anhydride with other unstable combinations of oxygen and sulphur.

The gases at a high temperature are unsuitable for disinfecting purposes, for although they possess disinfecting qualities they will bleach many of the articles exposed to their fumes. To prevent this, the gases are cooled down to near the temperature of the air by passing through coolers, and then they are ready to be pumped into the chamber or cabin to be disinfected. Attached to the Clayton apparatus is a fan for pumping purposes, with two tubes which are let into the chamber to be disinfected. The fan pumps the cooled gases through one tube into the chamber and exhausts the air from the chamber through the other, the withdrawn air being used to supply the burning sulphur in the furnace with air. This pumping and exhaustion continue until the air in the chamber contains nearly 5 per cent. of sulphurous acid gas. Before this stage is

reached, the exhaust pipe is shut off from the furnace, as air with this percentage of sulphurous acid gas becomes a fire-extinguishing gas, and the furnace is now supplied with air from the outside. The percentage of gas in the chamber soon rises to 10 per cent. or higher, but as 6 and 8 per cent. of saturation have been found to be bactericidal, it is not considered necessary to go beyond this. In fact later experiments by Dr. Wade for the Local Government Board show that a 3 per cent. gas destroys pathogenic bacteria in exposed places. A low percentage of gas appears to be more penetrative than a high percentage. The percentage of gas in the chamber is easily measured by drawing off some of the air in a graduated burette and noting the amount of gas absorbed by water. Fumigation by this method not only destroys bacteria and is, therefore, a true disinfectant, but it also destroys rats, mice, insects, weevils, beetles, cockroaches, lice, bugs, mosquitoes, and the eggs and larvæ of insects. It will not, however, destroy the spores of anthrax. A six-hours exposure to air, saturated to the extent of 6 or 8 per cent. of the gas, will destroy the bacillus of plague, diphtheria, cholera, typhoid fever, tuberculosis, and the infective agent of small-pox and vaccine. A two hours exposure to a 3 per cent. of the gas will destroy all kinds of vermin, or an average loaded hold on board ship may be thoroughly disinfected by fumigation by Clayton's apparatus with 3 per cent. sulphur dioxide for eight to twelve hours, provided that it be left closed until next day, while rats and insects are destroyed in less than two hours by the uniform diffusion of 0·5 per cent. of sulphur dioxide. This condition, as Dr. Wade shows, is easily and quickly realized in cabins and empty holds, and in the space around the cargo in a loaded hold; but owing to the extensive absorption of this gas, air containing 3 per cent. of it must be circulated around the cargo for eight to twelve hours to secure adequate penetration. Owing to these properties the Clayton gas is particularly service-

able for disinfection in the Tropics, where so many diseases are carried by insects. It is used for the destruction of rats on ships coming from plague-infected ports, and for the disinfection of the holds while the cargo is on board. It is, however, destructive to fruits and spoils potatoes, and it is liable to injure wheat in bags, but for wheat in bulk, maize, rice, and other staple grains, it is harmless, and is now used to preserve these from weevil and other parasites. Fumigation by the Clayton gas is one of the most useful and reliable defences against the importation of disease by infected ships. For disinfection of houses it has the advantage over other means of disinfection, that nothing need be removed from the infected hut or house, and it is superior to formaldehyde, which has little penetrative power. Instead of taking some of the articles to a central station, all that is required is to take the Clayton apparatus to the infected house and fumigate the house or hut with its contents. Everything is thus disinfected *in situ* with one operation, and the troubles connected with the existing systems saved. At the same time, the destruction of vermin and the more thorough disinfection it secures give to the process advantages which belong to no other method.

A precise method of testing the effect of the fumigation is to place some fresh cultures of bacilli on agar and on sterilized wool in tubes in different positions in the room or hold to be fumigated, and after the fumigation to ascertain by culture whether they are all destroyed.

Formaldehyde is effective for the fumigation of rooms, which may be carried out in various ways. The gas may be generated by vaporizing tablets of paraformaldehyde with the "Alformant" lamp (thirty tablets per 1,000 cubic feet); by spraying formalin with the "Equifex" spray, or simply saturating hanging sheets with formalin; or by mixing formalin with fine crystals of potassium permanganate in a metal vessel (1 pint of formalin and 10 oz. of permanganate per 2,000 cubic feet).

CHAPTER XV.

VILLAGE AND TOWN SANITATION IN RELATION TO MALARIA AND OTHER DISEASES CAUSED BY THE MOSQUITO.

In Villages and Towns preventable Insanitary Conditions play the ruling part in the maintenance of Malaria.—Malaria, before Manson and Ross solved the problem of the causation of the disease, was attributed to bad air and bad water, and numerous instances can be given of a change having been effected in a locality by the introduction of good water, drainage and conservancy.

The discovery of the *rôle* of the mosquito in the causation of malaria does not diminish the importance of these practical measures of sanitation, but emphasizes the necessity for them in malarious countries.

Wherever there is bad air it is almost invariably due to absence of proper conservancy, efficient drainage, and healthy construction of houses and streets. It is under these conditions that urine, slop water and rain water collect on the ground in or around habitations and breed mosquitoes, which find shelter in crowded and dark houses and propagate and maintain malaria.

It is the same with bad water. Bad water as a rule means a supply from pools, water-holes, shallow wells, and unprotected tubs and tanks, every one of which breeds mosquitoes.

Repetition of Insanitary Conditions is the cause of Malaria in new Villages and Towns.—These conditions exist in old villages and towns in malarious countries, and when new villages and towns arise owing to fresh developments in trade and transit there is a repetition of the same

insanitary conditions that characterize and render unhealthy the old. Thus :

(*a*) The selection of a site, instead of being a subject of consideration and foresight, is left more or less to chance, irrespective of elevation or relation to marsh or river. If the site selected is good and high, and not too near a river or marsh, it is seldom sufficiently cleared so that the outermost huts have a clear space of some 400 yards from the thick undergrowth.

(*b*) The same mistakes are repeated with reference to excavations. Every hut or building erected has the material of which it is made, whether of mud, sand or gravel, taken from the ground in the immediate vicinity of the hut or building. No inhabitant, contractor, or official should be allowed to dig an excavation for building material less than a mile distant from the boundary of the proposed town or village. This is no hardship in tropical and malarious countries, for the people there think nothing of carrying loads long distances. It is not the poor ignorant people of the country who alone do this. Contractors, and not infrequently engineers, are just as great offenders in this respect. If gravel or clay or other material is near at hand, they immediately make an excavation and create a malarial breeding-place, and do thereby, unintentionally no doubt, an infinite amount of harm. Sanitary work is often considered to be costly, but the most costly is generally that which has to rectify mistakes such as these, which could easily have been avoided.

(*c*) No plans of the proposed village or town are drawn out. The alignment of the huts and houses and the air spaces behind are generally neglected, and hence insanitary areas are formed which are very difficult to drain effectively, and cost large sums to clear.

(*d*) The water supply is seldom thought of and arranged for so as to prevent the breeding of mosquitoes. The result is all sorts of devices for collecting and storing water are brought into requisition, and in a short time the new town or village is as malarious as any older one.

As prevention is better than cure and in sanitary matters less costly, great attention should be paid to the sites and developments of new villages and towns, in order that the insanitary conditions mentioned, favouring the development and prevalence of malaria, shall be prevented from arising. It should be a guiding principle in sanitation that no malaria shall be allowed to arise or exist in a new village or town even in a malarious country.

As regards villages and towns already malarious, there are two classes: those built in the midst of the marshes and swamps of lagoons and deltas of rivers, and those not built under these unfavourable conditions, but possibly having marshes near them.

Preventive Measures in old Villages and Towns in the midst of Marshes.—Taking the first class, which is not a large one, palliatives seem at present to be the only measures practicable for Europeans. These consist of: (*a*) Taking of quinine regularly for prophylactic purposes. Some take five grains a day, others take ten grains on two consecutive days twice a week. The quinine should always be taken with food. (*b*) Living in a mosquito-proof house. (*c*) Personal protection from bites when out in the evening by mosquito boots, gloves, &c. (*d*) Early retirement at night-time. (*e*) Sanitary measures immediately around the house. (*f*) The gradual extension of the distance between the marsh and habitations by bunding to prevent the encroachment of tidal waters from lagoon, creek, or marsh, and the filling up and draining of the swampy ground between the residences and the swamp. Such conditions, however, are rare, except in the case of the coast on the Bight of Benin, the deltas of some great rivers, and the sites of old trading stations where the merchants or traders not infrequently located their factories on the low-lying and swampy land close to the river or lagoon when there was often high and healthy land immediately behind.

In the last instance the factories even now can be used

during the day, provided residential houses are erected on the high lands behind to serve for the protection of the merchants, traders, and officials during the night.

A country may have many swamps and yet not be malarious to the inhabitants living in villages or towns. Even marshes too great in extent to be filled up or to be drained, and not far from a village or town may be blamed for malaria when the cause is nearer. A good deal of misconception prevails in regard to marshes and the *rôle* they play in the causation of malaria. While a marsh perhaps a mile away or more, and from which the prevalent wind does not blow towards the village or town, is pointed out as the origin of the ill-health of the town, the real important factor or factors are in the village or town itself, and consist in its insanitary condition and in that of its immediate surroundings.

Marshes, lagoons and swamps are bad enough, but, like climate, they have been blamed for ills with which they have often had little or nothing to do.

The man who drinks too much, who leads an irregular life, who exposes himself recklessly to the sun or other well-known conditions unfavourable to health in the Tropics, without any attempt at precautions which others more sensible take care to employ, attributes most of his ill-health to the climate. No one will deny that the climate is a contributing factor, but in his case a very small one. Some climates have a very enervating effect on the European, causing debility, tropical heart, and strain on the nerves, but with ordinary precautions few climates are so destructive to health as this man makes out.

Similarly it is not infrequent that the man who is loudest in his condemnation of the manner in which the natives live, and who apparently realizes that their insanitary conditions cause malaria in them, will, when himself attacked with fever, attribute it to a marsh a mile or more away, or to all sorts of unusual phenomena, which an inspection shows is due to the insanitary

condition of his own premises favouring the breeding of Anopheline and other mosquitoes.

Malaria will disappear with Good Sanitation.—In most cases malaria would disappear with the introduction of a good water supply, good drainage, good paving, good conservancy, good building regulations, and an organized sanitary service to see carried out and maintained systematically and continuously as a matter of routine the requisite measures of sanitation.

A good and plentiful supply of pure water brought into every street of a town does away with the need of an enormous nnmber of storage tanks in the shape of underground reservoirs, iron tanks, cisterns, and vats and tubs outside the houses; it also abolishes the need of pools, ponds, exposed surface wells, and similar arrangements for collecting and storing water, which at the same time are perfect nurseries for mosquitoes.

When these collections of water exist the introduction of a public water supply admits of their being quickly abolished, which can hardly be done on a large scale if there is no water supply to take their place.

With the introduction of a water supply, drainage must also be provided at the same time, for if water is brought into a town, arrangements must be made to take it out, otherwise pools and dampness and the conditions for the prevalence of malaria only re-appear in another form.

Preventive Measures in old malarious Towns.—The sanitary measures mentioned go to the root of the matter for the prevention of both malaria and other preventable diseases. This is what should be ultimately aimed at. In the meantime, when Europeans have to reside in a malarious town or village, certain precautions are necessary :

Firstly, the prophylactic taking of quinine.

Secondly, the segregation of the residential quarters of the Europeans away from the native town. The business quarters, if in the neighbourhood of the natives, should only be occupied during the day.

Thirdly, the provision of a good water supply. If there is no public supply—which is by far the most effective against malaria—then the rain water should be stored in tanks containing at least 7,000 to 10,000 gallons each, and these should be in duplicate for the purpose of obtaining a sufficient quantity to allow of the tanks being cleansed during the rainy season. These tanks should always be above ground, unless on rapidly shelving ground, in order to permit of them being emptied and cleaned, and should be so constructed as to be capable of being rendered mosquito-proof by wire netting. To secure that they do not breed mosquitoes owing to some unseen defect in the wire netting, a small quantity of kerosine should be poured into them once a week. As the kerosine floats and does not dissolve in the water there is no risk of the water drawn from the tap situated at the lower part of the tank being affected by the kerosine.

The gutters of the roof should be perforated and well laid, so that no water shall lodge in them and thereby form pools. A little kerosine poured into these gutters during the rainy season is an additional precaution. When the water supply is from wells the water should be drawn by pump and the well should be protected.

Fourthly, a surface drain round the house and round the tanks or cisterns is necessary to prevent the rain which falls from the roofs of the house or tanks accumulating in pools. These drains ought to be connected with the surface drains outside the premises. The same should exist for the outhouses, and care should be taken that these surface drains are maintained in proper repair. The paving round the house and the grassplot have already been referred to as additional safeguards. They prevent puddles from being formed.

Fifthly, as most European houses have extensive compounds or should have, these should be kept scrupulously clean and always free of undergrowth. Large tubs with shrubs in them should not be kept near the house.

During the rains they often contain larvæ. No pool should be permitted on the premises for garden or other purposes.

Sixthly, the lower part of the house should be light and thoroughly well ventilated, and there should be no combination of general stores below and dwelling rooms above. Such an arrangement only means dark and closed-up rooms below, which are harbingers for mosquitoes that hide there during the day and invade the dwelling rooms upstairs at night.

Seventhly, latrines and bath-rooms should always be light and airy. If possible they should be detached from the house and approached by a covered passage. It is a great mistake to have them downstairs in a dark and badly ventilated situation. They should be light and airy, and their entrances and windows should be protected by wire netting. Latrines are particularly attractive to mosquitoes.

Eighthly, the kitchen and outhouses require special attention. Servants will keep tubs, jars or tins full of drinking or sullage water, or make pools by throwing the latter on to the ground from the kitchen or their rooms. They will also throw jam tins, sardine tins, bottles or other rubbish on the ground behind the kitchen or out-offices. Unless these and their surroundings are regularly inspected by the occupant of the house and everything obnoxious of this kind cleared away, there will arise plenty of opportunity for mosquitoes to breed. The same remarks apply to the servants' latrines. The occupier of a European house should be held responsible for keeping his premises and those of his servants clean and free of mosquito-breeding conditions, and should be prosecuted if he fails to do so.

Outside the boundaries of the premises it becomes the duty of the Government or the Municipality to keep the village or town clean and free of mosquitoes, and charge accordingly, or if there are vacant lands to see that the owners keep them clean and free of mosquitoes.

To do this a sanitary staff must be maintained, its duties being:—

(1) To see that owners and occupiers of houses and land keep their premises clean and free of mosquito-breeding places.

(2) To remove sewage and refuse of all kinds.

(3) To keep watercourses and flood-water drains and culverts clean, properly graded and in good condition, and free of vegetation, and if pools are formed in them to kerosine them.

(4) To clear away undergrowth, long grass and jungle within the boundaries of the town, and make arrangements for clearance from land outside the municipal bounds for 500 yards.

(5) To fill up and drain excavations, pools, and low-lying lands where water is likely to lodge. Many marshes are at the foot of small hills, and material from the hill can be easily obtained to fill up the marsh. When this is done care should be taken in regard to levelling and grading.

(6) To limit the number of open drinking-water tanks compatible with a sufficiency of supply; to arrange for the rough filtration of this water, and to kerosine once a week the unfiltered water.

(7) To provide special tanks, well removed from huts and houses, for washing and bathing purposes.

A special branch of the sanitary staff should be daily and continuously employed throughout the year to regularly once a week treat every pool, pond, and tank or drain with kerosine, in such a manner as to cover the whole surface of the water lying in it. This measure should be supplemented by the prosecution of the occupier of any premises on which mosquito larvæ are found.

In a town the Sanitary Officer's daily report to the Health Officer should, among other details, include a filled-up printed form giving the work done in each sanitary district somewhat as follows:—

	Sanitary Districts.			
	1	2	3	4
(1) Number of inspectors employed				
(2) Number of houses inspected				
(3) Addresses of houses where larvæ were found				
(4) Number of notices served to remove conditions causing the breeding of larvæ ...				
(5) Number of persons fined for having mosquito larvæ on premises				
(6) Number of notices served to remove insanitary condition on premises ...				
(7) Number of persons fined for not removing insanitary conditions after notice ...				
(8) Number of linear feet of ditches cleaned...				
(9) Number of linear feet of ditches dug and graded				
(10) Number of square yards of weeds, grass, and vegetation cut and removed ..				
(11) Number of excavations filled up				
(12) Amount of low-lying land raised				
(13) Number of cubic yards of material used for filling up excavations...				
(14) Number of men employed for 8, 9, 10, 11, 12, and 13...				
(15) Number of persons fined for making new excavations without permission				
(16) Number of drains oiled				
(17) Number of pools oiled				
(18) Number of tanks and barrels oiled ...				
(19) Number of men employed for oiling drains, pools, and water tanks, or barrels ...				
(20) Number of carts at work to remove refuse from streets, and number of carts of refuse removed				
(21) Number of carts at work to remove refuse from yards and premises and number of carts removed				
(22) Number of men employed for removing refuse				
(23) Number of pails of nightsoil removed ...				
(24) Number of clean nightsoil pails installed...				
(25) Number of men employed on nightsoil duty				

It should be one of the Health Officer's duties to ascertain that these reports are correct, and that the work is being carried out regularly, systematically, fairly, and with judgment.

All plans also of houses, huts, and other buildings to be constructed should be submitted to the Health Officer for approval as to site, construction, and relation to other

buildings, before permission is given for commencement. Neither should drains be permitted by the Health Officer to be cut or laid down except in conformity with a general plan which has been worked out and carefully arranged according to the levels and contours of the locality.

REFERENCES.

"The Bacteriological Examination of Water Supplies." By William G. Savage, M.D. 1906.

"Diet and Dietetics." By A. Gautier; translated by A. J. Rice Oxley, M.D. 1906.

"The Purification of Sewage." By Sidney Barwise, M.D. 1904.

"The Parasites of Man." By Rudolph Leuckart; translated by W. E. Hoyle, M.A.Oxon., M.R.C.S., F.R.S.E. 1886.

"Manual of Bacteriology." By R. Tanner Hewlett. 1908.

"Laboratory Studies in Tropical Medicine." By C. W. Daniels. 1908.

"Food Grains of India." By A. H. Church, M.A., F.C.S., F.I.C. 1886 and 1901.

"Food and the Principles of Dietetics." By R. Hutchison, M.D. 1900.

"A Practical Guide to Meat Inspection" (Walley). Re-written by Stewart Stockman, M.R.C.V.S. 1901.

"Sanitary Handbook for India." By Surgeon-Major C. J. McNally, M.D. 1889.

"The Causes and Prevention of Beri-beri." By W. L. Braddon, M.B., B.S., F.R.C.S. 1907.

"The Medical Diseases of Egypt." By F. M. Sandwith. 1905.

"Hygiene and Diseases of Warm Climates." Edited by Andrew Davidson, M.D. 1893.

"Food for the Tropics." By T. M. MacKnight. 1904.

Colonial Medical Reports issued by the several Colonial Governments.

Reports of the Sanitary Commissioners with the Government of India and the Reports of the Sanitary Commissioners for the different Provinces in India.

The Indian Medical Gazette.

The Journal of Tropical Medicine and Hygiene.

The Journal of the Malaya Branch of the British Medical Journal.

Scientific Memoirs of the Medical Officers of the Government of India.

SUMMARY OF PREVENTIVE MEASURES EMPLOYED IN SOME OF THE MORE COMMON INFECTIOUS DISEASES PREVALENT IN THE TROPICS.

Class	Name of disease	Causal agent	Modes of entrance into human body	Modes of exit	Modes of spread	Preventive Measures			
						Personal protection in a district where disease is endemic	Domestic measures to prevent spread of disease when a person is ill	General measures in a district where disease is endemic	Special measures where disease is prevalent
Bacterial	Cholera	Koch's comma bacillus	(1) Infected water (2) Infected milk (3) Infected food (4) Contamination of mouth by infection	(1) The bowel discharges	(1) Infected water (2) Infected milk (3) Infected food (4) Flies (5) Infected clothes (6) Human carriers with the bacillus in their stools	(1) Boil water (2) Boil milk (3) Cook vegetables (4) Avoid salads and fruits (5) Inoculation (6) Treat dyspepsia	(1) Isolate patient (2) Disinfect stools, and boil or burn (3) Disinfect all bedding and soiled articles (4) Disinfect spoons and utensils used by patient (5) Boil milk (6) Boil water (7) Protect food and house from flies (8) Disinfect house	(1) Secure good and pure water supply (2) Secure good and pure milk supply (3) Secure good and pure food supply (4) Remove nuisances giving rise to or attracting flies	(1) Ascertain special cause of disease, and deal with that cause (2) Sort out the suspected human carriers by examination of fæces (3) Protect all water supplies and milk supplies (4) Inoculation

SUMMARY OF PREVENTIVE MEASURES.—*Continued.*

Class	Name of disease	Causal agent	Modes of entrance into human body	Modes of exit	Modes of spread	Preventive Measures			
						Personal protection in a district where disease is endemic	Domestic measures to prevent spread of disease when a person is ill	General measures in a district where disease is endemic	Special measures where disease is prevalent
Bacterial	Malta fever	Bruce's *Micrococcus melitensis*	(1) Drinking infected goat's milk the most frequent (2) Infected water (3) Infected milk (4) Infected food (5) Inoculation	(1) Bowel dejecta & urine	(1) Goats' milk (2) The urine of goats (3) Cows' milk and urine (4) The urine of infected dogs, sheep and horses (5) Infected clothes (6) Infected houses	(1) Avoid goats' milk or boil it thoroughly (2) Boil all cows' milk (3) Keep in a cleanly and disinfected condition all kennels, stables, and other places for animals kept on the premises (4) Provide good latrines for house	(1) Disinfect bowel discharges and urine (2) Disinfect all articles used by the patient (3) Disinfect house and household goods (4) Disinfect all latrines on premises (5) Protect patient with a mosquito net (6) Protect food from flies (7) Boil milk (8) Boil water	(1) Boil all milk (2) Boil water (3) Protect water supply & milk supply from becoming contaminated with sewage (4) Protect milk supply & food supply from being contaminated by flies which have been on sewage (5) Provide good latrines	(1) Ascertain special cause and deal with that cause (2) Sort out human carriers by examining urine and having the urine & latrines used disinfected (3) Sort out goat carriers, prevent their milk being sold, and disinfect the premises where they are kept (4) Disinfect all public latrines and urinals

Class	Name of disease	Causal agent	Modes of entrance into human body	Modes of exit	Modes of spread	Preventive Measures			
						Personal protection in a district where disease is endemic	Domestic measures to prevent spread of disease when a person is ill	General measures in a district where disease is endemic	Special measures where disease is prevalent
(1) One form, Bacterial (2) Second form, Protozoan	Dysentery	(1) Shiga and Flexner's bacillus and other bacilli (2) *Amœba coli* (?), and *Entamœba histolytica* (3) *Balantidium coli*	Infected water Infected milk Infected salads Use of infected latrines	Discharges from bowel	(1) Insanitary latrines or polluted soil, infected boots, clothes, hands, &c., or flies, afterwards infecting food (2) Water infected with bowel discharges (3) Uncooked vegetables contaminated with fæcal discharges (4) Milk infected with contaminated water (5) Possibly jungle water	Boil water and milk Avoid uncooked vegetables Prevent misuse of latrines or their surroundings	(1) Disinfect excreta and then boil or burn (2) Thoroughly disinfect by boiling all articles used by patient (3) Disinfect house and latrines	(1) Keep latrines clean & disinfected (2) Provide a sufficiency of latrines for encampments of coolies, soldiers or others, and maintain them in a cleanly state (3) Prevent anyone using other places than latrines for defæcation or passing water (4) Keep the soil unpolluted (5) Provide pure water supply	(1) Protect all water supplies (2) Issue orders to boil water and milk. (3) Maintain latrines in a cleanly and disinfected state (4) Provide special pails for infected houses.

N.B.—Dysentery is more a jungle than a town disease amongst Europeans.

SUMMARY OF PREVENTIVE MEASURES.—*Continued.*

Class	Name of disease	Causal agent	Modes of entrance into human body	Modes of exit	Modes of spread	Preventive Measures			
						Personal protection in a district where disease is endemic	Domestic measures to prevent spread of disease when a person is ill	General measures in a district where disease is endemic	Special measures where disease is prevalent
Bacterial	Typhoid fever	Eberth's bacillus	(1) Infected water (2) Infected food— (*a*) Infected oysters and other molluscs (*b*) Infected salads (*c*) Infected milk (*d*) Other infected foodstuffs	Bowel dejecta & urine	(1) Infected water (2) Infected food (3) Human carriers of infection who from a previous illness still return in their fæces and urine the bacillus, or who are healthy persons but who have lived in an infected house or locality (4) Infected hands (5) Infected clothes (6) Flies	(1) Boil water (2) Boil milk (3) Cook vegetables (4) Avoid or cook oysters (5) Inoculation	(1) Isolate patient (2) Disinfect stools and urine and all discharges (3) Disinfect clothes, spoons, and utensils used by patient or nurse (4) Boil milk (5) Boil water (6) Protect house from flies (7) Give patient after illness urotropine or some other disinfectant (8) Disinfect house and bedding	(1) Secure good water supply (2) Secure good milk supply (3) Secure good food supply (4) If there is an oyster supply see that the nursing beds are not subjected to sewage contamination (5) Remove all nuisances giving rise to or attracting flies (6) Provide good latrines	(1) Ascertain special cause and deal with that cause (2) Sort out human carriers by examination of their fæces & urine and treat them (3) Inoculation (4) Protect all drinking water and milk supplies

						Preventive Measures.			
Class	Name of disease	Causal agent	Modes of entrance into human body	Modes of exit	Modes of spread	Personal protection in a district where disease is endemic	Domestic measures to prevent spread of disease when a person is ill	General measures in a district where disease is endemic	Special measures where disease is prevalent
Bacterial	Plague	Kitasato's and Yersin's bacillus	Infection through the skin Infection through mouth and intestines Infection through the air passages	(1) In bubonic variety in discharge of buboes (2) In septicæmic variety in the discharges from the body (3) In pneumonic variety in the sputum	(1) By infected rats (2) By infected fleas from infected rats (3) By infected food (4) Infected clothes (5) By inoculation through abrasions & wounds (6) In pneumonic variety by direct contagion from the sputum, & in septicæmic cases probably by contact with infected discharges	(1) Inoculation with Haffkine's prophylactic (2) Living in a well-built masonry house, free of rats, dry and well ventilated	(1) Isolate patient (2) Disinfect all discharges (3) Inoculate everyone who comes in contact, or has come in contact, with patient. Inoculate all the inmates of the house. If Haffkine's prophylactic not available use Yersin's serum (4) Disinfect house & everything in it with Clayton's apparatus to destroy rats, vermin and plague infection	(1) Examine rats of districts regularly for plague infection (2) Treat house or locality where plague rats found as plague infected (3) Push inoculation (4) Destroy rats systematically (5) Remove nuisance likely to attract rats to house premises	(1) Divide locality into sections (2) Examine rats bacteriologically from each section (3) Treat house or section in which infected rats found as plague-infected without waiting for plague cases (4) Destroy rats systematically with poison and Danysz virus (5) Isolate patients as far as possible (6) Inoculate all the inmates of an infected house (7) Disinfect all infected houses, destroying rats and vermin as well (8) Disinfect ships leaving port (9) Infected houses should be evacuated until disinfected (10) In case of mud and grass huts disinfect by burning them (11) In pneumonic cases isolate everyone who has come in contact with the cases, inoculate them, disinfect or burn clothes and bedding and disinfect or burn hut (12) In a village infected with pneumonic plague remove sick and healthy, separate them and put a cordon round to prevent escapes and spreading of the disease

Class	Name of disease	Causal agent	Modes of entrance into human body	Modes of exit	Modes of spread	Preventive Measures: Personal protection in a district where disease is endemic	Preventive Measures: Domestic measures to prevent spread of disease when a person is ill	Preventive Measures: General measures in a district where disease is endemic	Preventive Measures: Special measures where disease is prevalent
Protozoan	Malaria	Laveran's malarial parasite (parasites of malaria)	Bite of an infected Anopheline mosquito	Suction of the blood of an infected patient by the Anopheline mosquito	By Anopheline mosquitoes infected from persons with the sexual forms of the parasites of malaria in their blood	(1) Reside in a mosquito-protected house or at least provide a mosquito-proof room on verandah & one bedroom (2) Use a mosquito net for bed (3) Regular dosage with quinine if in a badly infected district (4) Destruction of all mosquitoes on premises and destruction of all breeding-places near or on the premises (5) Live in a house distant from large bodies of susceptible people, such as native children, troops or labourers from non-malarial districts (6) Have legs protected by mosquito boots or otherwise	(1) Isolate patient in a mosquito-protected room (2) Destroy mosquitoes on premises and destroy breeding-places on or near premises	(1) Destroy as far as possible all breeding-places for mosquitoes (2) Drain the locality (3) Remove nuisances, undergrowth, and receptacles likely to harbour mosquitoes (4) Open up dark and ill-ventilated portions of buildings and houses	(1) Provide facilities for administration of quinine (2) Protect windows and doors of houses with mosquito screens (3) Fumigate houses (4) Employ mosquito brigade for filling up small pools and puddles, cleaning drains, clearing away brushwood, pouring petroleum into cesspools & larger pools, remove nuisances (5) Improve drainage of locality

Class	Name of disease	Causal agent	Modes of entrance into human body	Modes of exit	Modes of spread	Preventive Measures			
						Personal protection in a district where disease is endemic	Domestic measures to prevent spread of disease when a person is ill	General measures in a district where disease is endemic	Special measures where disease is prevalent
Protozoan	Trypanosomiasis, or sleeping sickness	Forde and Dutton's *Trypanosoma gambiense*	Bite of an infected *Glossina palpalis* and possibly of other species of Glossina and other biting flies	Suction of the blood of an infected patient by *Glossina palpalis*, &c.	(1) *Glossina palpalis*	(1) Wearing of putties, gloves, fly proof boots, and hat net when in fly areas, also fly-resisting clothes (2) Sleeping under a mosquito net (3) Residing in houses provided with mosquito wire gauze in windows and doors (4) Periodic administration of atoxyl	(1) Isolate, and, if possible, send to a hospital outside fly area (2) Provide a mosquito proof room for patient	(1) Sort out persons with enlarged cervical glands, examine for trypanosomes, and isolate in areas away from fly areas (2) Clear undergrowth and bush on the banks of rivers and lakes near villages, fords and watering-places (3) Encourage destruction of flies (4) Fumigate houses and (5) Protect houses with mosquito wire netting against chance invasion	(1) Evacuate affected area.

SUMMARY OF PREVENTIVE MEASURES—*Continued.*

Class	Name of disease	Causal agent	Modes of entrance into human body	Modes of exit	Modes of spread	Preventive Measures			
						Personal protection in a district where disease is endemic	Domestic measures to prevent spread of disease when a person is ill	General measures in a district where disease is endemic	Special measures where disease is prevalent
Protozoan	Kala azar	Leishman-Donovan parasite	Probably by the bite of a bed-bug, *Cimex rotundatus*	Suction of the blood of an infected patient by the bite of a bed bug	The bed-bug	(1) Never to sleep in an infected hut or house (2) Fumigate and disinfect house to destroy all insect life	(1) Remove sick person to a new and clean house (2) Burn down infected hut with infected articles in it (3) Special methods for destruction of bed-bugs in beds, bedding, bedsteads, &c.	(1) Isolate in clean hospital or house the sick (2) Evacuate all infected houses (3) Burn down the infected hut with its contents, or fumigate with Clayton's disinfector (4) Systematically fumigate and disinfect houses and huts in the camp or village	(1) Prevent migration of the sick to healthy villages (2) Isolate sick (3) Evacuate any badly infected village and establish healthy persons on a healthy site (4) Burn infected village or systematically fumigate and disinfect every house (5) Disinfect all articles from an infected house before removal to a healthy house.

Class	Name of disease	Causal agent	Mode of entrance into human body	Mode of exit	Mode of spread	Preventive Measures			
						Personal protection in a district where disease is endemic	Domestic measures to prevent spread of disease when a person is ill	General measures in a district where disease is endemic	Special measures when disease is prevalent
Proto-zoan?	Yellow fever	?	*Stegomyia calopus* (*fasciata*)	*S. calopus*	*S. calopus*	(1) Protection from bites of mosquitoes day and night (2) Fumigate and destroy mosquitoes in house	(1) Enclose patient in portable mosquito-proof room (2) Destroy all mosquitoes that enter room (3) Destroy all mosquitoes in house	(1) Destroy all domestic mosquitoes (2) Careful search for breeding places and destroy them: (*a*) In house, jugs, bath-tubs, flower-pots; (*b*) roof-gutters and water-tanks; (*c*) empty tins, bottles, &c., in grass round house; (*d*) in servants' quarters	(1) Prevent migration of sick or of those who have been in contact with sick or living in infected districts. (2) Quarantine ships from infected ports, and fumigate and destroy any mosquitoes in them. (3) Quarantine people from such ships six days.

SUMMARY OF PREVENTIVE MEASURES.—*Continued.*

Class	Name of disease	Causal agent	Modes of entrance into human body	Modes of exit	Modes of spread	Preventive Measures: Personal protection in a district where disease is endemic
Protozoan	African tick fever	*S. duttoni*	By bites of infected ticks (*Ornithodoros moubata*)	*O. moubata*	*O. moubata*	(1) Sleep on beds raised from ground; better, with legs of bed in glazed pots (2) Destruction of ticks
Protozoan	Relapsing fever	*Spirochæta obermeieri*	(?) *Pediculus vestimenti*, (?) bed-bug	(?) *P. vestimenti*, (?) bed-bug	(?) *P. vestimenti*, (?) bed-bug	Destruction of vermin

INDEX.

ABLUTION water, 196
Acclimatization, 12, 14
Acids, fatty, in ghee, 191
Actinic rays, 16
Actinomycosis, 163
Adam's process, 186
Adulteration of milk, 180
African tick fever, 386
Air, ground, 292
Alcohol, 21, 22
Algæ in water, 49
Alimentary principles, 109
Allahabad system of trenching, 233
Alum, purification of water by, 71
Ammonium chloride, 46
Anchylostomiasis, 18
Anchylostomum, 63, 343
Anderson's process, 72
Anguillula tritici, 151
Animal foods, 113
Animals, diseases conveyed by, 160
— inspection of, 161
Anopheline mosquitoes, 382
Anti-splash pails, 204
Aquatic plants, 50, 51
Areas, building, 306
— insanitary, 297
Artesian wells, 44
Arthropoda, 343
Aspergillus, 147
Asylums, leper, 323

Bacillus botulinus, 158
Bacillus coli, characters of, 104
— — flaginac test for, 106
— — in water, 107
Bacillus enteritidis, 158
Bacillus enteritidis sporogenes, 158
Bacillus typhosus, characters of, 103
— — isolation from milk, 155
— — isolation from water, 101
Bacterial beds, 273, 275, 277
— infections, 344
Bacteriolysis of sewage, 269
Bathing, 18
Baths, 18
Bean, mung, 129
— soy, 113
Bed, 20
Bed system (sewage), 268
Beggiatoa, 50
Beriberi, 142
Berkefeld filter, 99
Bibliography, 376
Bile-salt medium, 107
Bilharzia, 8, 18
Bilharziosis, prevention of, 353
Biological treatment of sewage, 270
Bladder worms, 164
Blood, change in distribution of, 13
Body temperature in Tropics, 12
Boiling of water, 85
Borates in food, 193
Borrow pits, 284
Bottles, removal of, 247
Breezes, factors producing, 3
Bricks for damp course, 313
Broad irrigation (sewage), 266
Buckets for removal of excreta, 198
Buffalo milk, 181
Building areas, 306
— by-laws, 308

Bunt, 149
Burial grounds, 39, 292
Butter, 114
By-laws, building, 308

Calandra oryzæ, 150
Calcutta, life in, 10
— sewage carts of, 224
Calories, 116
Camps, 33
Camping ground, selection of, 25
Cantonments, sanitation of, 256, 274
Carbohydrates as food, 110
— influence on fatigue, 137
Carbonic acid given off, 14
Carcases of animals, 160
Carts for sewage, 223
— for removal of excreta, 198
Cassava, 114
Catchwater system (sewage), 268
Cattle, tuberculosis of, 163
Cereals, 112
— composition of, 115
Cesspits in vicinity of wells, 37
Cesspools, 227
Chara in water, 50
Chemical disinfection, 362
Chill, 18
Chilled meat, 159
Chinese latrines, 202, 209
— system of sewage disposal, 237
Chlorine disinfection, 363
— for sterilizing water, 82
Cholera, 340, 346
— conveyed by milk, 153
— isolation from water, 100
— preventive measures against, 377
— vaccination, 346, 350
Church's standard diets, 128
Circle of influence (wells), 34
Cladothrix, 50
Claviceps purpurea, 148
Clay pits, 284
Clayton disinfector, 364
Climate, 1
— and mortality, 9
— physiological effects of, 11
— relation of food to, 133
Climates, island, 3
— factors influencing, 3
— insanitary conditions attributed to, 8
Clothing for Tropics, 18
Coccidium, 175
Cocoanut plantations for trenching grounds, 235
Commode, 219
Communicable diseases, 339
Composition for damp course, 312
Conduits, open, 55
Congestive diseases, 15
Conradi-Drigalski medium, 108
Conservancy, 195
Contamination of rain water, 28
— of water, detection of, 45
— of wells, 34, 39
Convention, Paris, 354
Copper sulphate for purification of reservoirs, 51
— — for sterilizing water, 84
Corrosive sublimate, disinfection by, 363
Cotton's test, 183
Course, damp, 312
Cow-houses, 319
Cows' milk, 181
Crenothrix, 50
Crops, jail trenching grounds, 335
— for sewage farms, 269
Crowley's night soil cart, 224
Cubic space for jails, 325
Cubicle system for hospitals, 320
Cultivation, effect on locality, 291
Cyllin disinfectant, 363
Cysticerci, 164, 172
Cysticercus bovis, 164, 172
— *cellulosæ*, 164, 172
— *tenuicollis*, 172
Cysts, hydatid, 172

Damp course, 312
Dampness of houses, 312
Danysz virus, 347
Decomposition of food on keeping, 156
Deposits in water pipes, 67
Depots, emigration, 323
— sewage, 255
Destructor, Donaldson's, 336

Diamond drill, 41
Diarrhœa caused by water, 68
Dibothriocephalus latus, 177
Diet for adults, 130
— for children, 130
— monotony of, 130
— rice, defects of, 138
Dietaries, construction of, 124, 128
Diets, 117, 118, 119, 121, 123
Chittenden's diet scale, 119-121
Rubner's standard diet, 117
Voit's standard diet, 117
Diseases caused by impure water, 67
— communicable, 339
— congestive, 15
— conveyed by animals, 160
— endemic, 8, 341
— epidemic, 341
— food in relation to, 132
— geographical distribution of, 8
— infectious in jails, 335
— manifestations of, 340
— nervous, 15
— of liver, 21
— pandemic, 340
— preventive measures against, 377-386
Disinfection, 346, 360
— by burning, 360
— by heat, 360
— chemical, 354, 362
— in hospitals, 322
— steam, 361
Disinfectors, 361, 362, 364
Disposal of sewage, 221
— of waste matters, 195
Distomum, 175
Disturbance of soil, 291
Donaldson's destructor for jails, 336
— ejector, 333
Dormitories of jails, 327
Dracunculus, 63
Drains, 249
— around houses, 313
Drainage of soil, 282, 288
— into wells, 34
— water supply without, 286
Drigalski-Conradi medium, 108
Drink in Tropics, 21, 22

Dry earth closets, 322
Dysentery caused by water, 68
— preventive measures against, 379
— scorbutic, 9

Eaves to houses, 313
Echinococcus cysts, 172
Ecliptic, 1
Effect, physiological, of climate, 11
Effects, physiological, of Tropical climates, 11
Emigration depots, 325
Endemic diseases, 340, 341
Environment, effect of, on body, 11
Epidemic diseases, 340, 341
Ergot, 148
Ergotism, 148
Examination of water, 97, 100
Excreta, amount of, 196
— buckets and pails for, 198, 204, 217
— carts for, 198
— conversion into poudrette, 239
— disinfection of, 353
— disposal of from jails, 333, 336
— trenches for, 201
Europeans, physiological effects of Tropical climates on, 11
Exercise, effects of, 13
— in Tropics, 17
Exposure to heat, 11

Factories, 323
Famine code, diet, 123
Farms, sewage, 267
Fatigue, influence of carbohydrates on, 137
Fats as foods, 110
Fatty acids in ghee, 191
Fermentation in the Tropics, 7
Festivals, 323
Fever, malarial, 367, 382
— Malta, 378
— relapsing, 386
— Texas, 162
— tick, 162, 386
— typhoid, 351, 380
— yellow, 354, 385
Filariasis, prevention of, 353

Filters, Berkefeld, 99
— examination of, 97
— mechanical, 95
— Pasteur-Chamberland, 98
— sand, 91
Filtration, conditions for efficient, 93
— downward (sewage), 267
— of water, 60
— sand, 91
Fish, poisonous, 176
— stale, 176
Flaginac test for *B. coli*, 106
Flies and trenching grounds, 234
— spreading small-pox, 346
Floodings, effect of, 288
Flour, *acarus* of, 151
— *anguillulæ* of, 151
Fluorescin, 45
Food, decomposition of, on keeping, 156
— kind of, for Tropics, 136
— in relation to disease, 132
— in Tropics, 21
— supply, 109
Foods, animal, 113
— classification of, 110
— constituents of, 125-127
— preservatives in, 193
Forbes' sterilizer, 86
Formaldehyde disinfection, 354, 363
— in milk, 193
Foundations of houses, 311
Fruits, 114
Fumigation, 363
Fungus, ray, 164

Garbage, disposal of, 240, 243
— fermentation of, 245
— gas from, 246
Garments, for Tropics, 18
Gathering grounds, 54
Geneste sterilizer, 85
Ghee, 114
— adulteration of, 189, 190
— analysis of 190
— kinds, 188
— preparation of, 188
— standards for, 190
Glossina palpalis, 341, 343, 383

Goddard, Massey and Warner's disinfector, 362
Grain, disinfection of, 151
— preservation of, 151
— unwholesome, 141
Grains, 112
Grass around houses, 313
Graveyards, soil of, 292
Griffiths' sterilizer, 89
Ground air, 292
— water, 26, 32, 50
Gunny bags, 151

Haffkine's prophylactic, 347, 348, 381
Health, food in relation to, 132
Heat, exposure to, 11
— value of foods, 116, 118
Height of houses, 305
Helminthes, 342
Hewetson's process, 72
Hoffman-Ficker method, 101
Horbury latrines, 204
Hospitals, 320
Houses, cow, 319
— dampness of, 312
— drains around, 313
— eaves to, 313
— foundations of, 311
— height of, 305
— hygiene of, 294
— requisites for, 308, 311
— roofs of, 313, 314
— slaughter, 318
— walls of, 311
Humidity, 4
Huts, 314
— regulations for, 316
Hydatid cysts, 172
Hydro-pneumatic system, 258
Hygiene of houses, 294
— — streets, 294

Ill-health, influence of climate on, 10
Indian jail, 328
— privies, 253
Infection, limitation of, 343
— nature of, 342
— prevention of, 345

Infections, bacterial, 344
Infectious diseases in jails, 335
Insanitary areas, 297
— — and tuberculosis, 301
— — methods of dealing with, 301
— conditions and climate, 8
Inspection of reservoirs, 52
Iodine for sterilizing water, 81
Iron roofs, 314
Irrigation, broad (sewage), 267
— effects of, 289
— regulation of, 290
Island climates, 3
Isolation, 346
Isotherms, 2

Jails, 325
— diet in, 130
— disposal of exereta, 333
— Indian, 328
— infectious diseases in, 335
— latrines for, 330
— trenching excreta, 334
— water supply of, 329

Kala-azar, preventive measures against, 384
Kerol disinfectant, 363
Kerosine for preventing malaria, 372
Klein's method for isolation of *B. typhosus*, 102

Lactometer, 184
Lakes, artificial, 49
— water of, 48
Land treatment of sewage, 266
Lanes, back, 307
Lathyrism, 147
Latrines, 200, 202-221
— combined with septic tank, 237
— connected, 256
— for jails, 330
— in houses, 249, 253
— oriental, 211
— separation of solids from fluids, 207
Laws, by-, for building, 308
Leeches in water, 69
Leffman-Beam process, 185
Leguminous grains, 112
— seeds, composition of, 115
Lentil, 113
Leper asylums, 323
Lime for purification of water, 72
Lithium chloride, 45
Liver, diseases of, 21
Local Government Board disinfectant, 363

MacConkey's bile-salt medium, 107
Macfarlane latrines, 216
Madras famine code, diet, 123
Maggot-breeding by Chinese, 238
Maiche sterilizer, 87
Maignen's process, 72
Maize and pellagra, 146
Malachite-green media, 103, 108
Malaria, disappearance of, with sanitation, 371
— insanitary conditions in relation to, 367
— preventive measures against, 369, 371, 382
— quinine prophylaxis, 371
— sanitation in relation to, 367
Malta fever, conveyed by milk, 152
— — preventive measures against, 378
Manioc, 114
Markets, 318
Marshes, 286, 287
Mashak, 64
Mauritius water supply, 73
McNally's constituents of foods, 125
Measles of meat, 164
Meat, characteristics of good, 156
— chilled, 159
— effects of excess of, 134
— illness caused by bad, 157
— poisoning, 158
— preserved, 159
— refrigerated, 159
Melbourne water supply, 53
Mercuric chloride, disinfection by, 363
Metal vessels for water, 64
Microbes in soil, 292
Micrococcus ureæ, 270
Milk, adulteration of, 180
— analysis of, 183, 184, 186

Milk, buffalo, 181
— cows, 181
— diet, 123
— diseases caused by, 152, 187
— preservatives in, 193
— scale, 186
— souring of, 152
— standards for, 180, 182
Millet, 112, 116
Moisture given off, 14
Moleschott's standard diet, 129
Mortality and climate, 9
— decrease of, 10
Mosquito net, 20
Mosquitoes breeding in bottles, 247
— destruction of, 370
Moth, 113

Nervous diseases, 15
Net, mosquito, 20
Neurasthenia, 21
Night-soil buckets, 222
— carts, 224
Nitrification of sewage, 269
Nitrites, test for, 183
Nitrogenous constituents of diets, 121
Non-nitrogenous constituents of diets, 121
Nutritive principles, 111
— ratio, 121

Oils, 113, 114
Open spaces, 305
Orange coloured clothing, 16
Ova in water, 69
Oxygen inspired, 14
Ozone, sterilization of water by, 75

Pandemics, 340
Paragonimus westermani, 171
Parasites, geographical distribution of, 7
— preventive measures against, 352
Paris Convention, 354
Pasteur-Chamberland filter, 98
Pea-nuts, 113
Peas, 112
Peat in gathering grounds, 54
Pellagra, 146
Perchloride of mercury, disinfection by, 363
Permanganate of potash disinfectant, 363
— — — for disinfecting wells, 81
Persons not adapted to live in Tropics, 12
Petroleum, 46
Phthisis, mortality from, 9
Physiological effects of Tropical climates, 11
Pilgrimages, 33, 323
Pipes for water, 66
Piroplasma bigeminum, 162
Pits, borrow, 284
— clay, 284
— sand, 284
Plague and rats, 347
— preventive measures against, 381
Planning of streets, 305, 307
— — towns, 303, 307
Plantations, 323
Plants, aquatic, 50, 51
Platforms of water closets, 251
Pleuro-pneumonia, 163
Pneumonia, pleuro-, 163
Poisoning by meat, 158
Port Swettenham, drainage of, 289
Porter-Clarke process, 72
Ports, organization for, 355
Potassium permanganate disinfectant, 363
Potato, sweet, 114
Poudrette, 239
Prawns, poisonous, 176
Precipitation processes (water), 71
— of sewage, 270
Preservatives in food, 193
Principles, alimentary, 109
— nutritive, 111
Prisoners, gauging health of, 337
— infectious diseases among, 335
Privies, 204
— Indian, 253
— shaft, 252
Prophlactic, Haffkine's, 347, 348, 381
Prophylaxis, quinine, 371
Protection of wells, 35
Proteids as foods, 110

Protozoa, 342
Ptomaines in meat, 158
Puccinia graminis, 149
Pulses, 112
— composition of, 115
Purification of water, 70-99
— Anderson's process, 72
— filtration, 90
— Hewetson's process, 72
— Maignen's process, 72
— Ozone process, 75
— Porter-Clarke process, 72
— precipitation processes, 71
— sterilization by chemicals, 81
— — — heat, 85, 90
Putrefaction in the Tropics, 7

Quarantine, 358
Quinine prophylaxis, 371

Rain, amount falling, 243
— separator, 29
Rainfall, 5, 24
— amount of, 6
— character of, 5
— effect on sewage disposal, 195
— seasons of, 6
Rain water, amount available, 27
— collecting, 26
— contamination of, 28
— storage of, 27
Raji, 112, 116
Rangoon, latrines in, 256
Rats and plague, 347
— destruction of, 347
— poisoning, 348
Ray fungus, 164
Rays, actinic, 16
Reck's disinfector, 362
References, 376
Refractometer, 190
Refrigerated meat, 159
Refuse, disposal of, 243
Regulation of irrigation, 290
Reichert-Wollny method, 191
Relapsing fever, preventive measures against, 386
Removal of sewage, 221
Report, daily, of sanitary officer, 374
Reservoirs, construction of, 51
— inspection of, 52
— purification of, 52
Residence, prolonged, in Tropics, 11
Resorcin test, 184
Rice, 116
— and beriberi, 142
— diet, defects of, 138
— storage of, 145
— weevil, 150
Richmond's slide rule, 186
Rickets, 141
Ridged surfaces (sewage farms), 268
Rinderpest, 162
Rivers as sources of water, 57-59
— self-purification of, 58
Roofs, 313, 314
Rye and ergotism, 148

Salicylic acid in foods, 194
Salt, 45
Salts as foods, 111
Sand-flies, 20
Sand pits, 284
Sanitary officer's report, 374
Sanitary staff, duties of, 374
Sanitation in relation to malaria, 367, 371
— of jails, 325
Schistosomum hæmatobium, 175
Schizomycetes, 342
Scott-Moncrieff system, 273
— Robert's modification, 274
Scurvy, 139
Season, rainy, 6
Segregation of natives, 371
Separator, rain, 29
Septic tank combined with latrines, 237
— — combined with trenching, 236
— — system, 171
Sewage, artificial treatment, 270
— bacterial beds, 273, 275, 277
— bacteriolysis of, 269
— biological treatment, 270
— broad irrigation, 267
— carts for, 223
— conversion into poudrette, 239
— depots, 255

Sewage, disposal by water carriage, 248
— — of, 221, 229, 265
— downward filtration, 267
— farms, 267
— — crops for, 269
— gas from, 280
— hydrolytic tanks, 275, 277
— land treatment of, 266
— natural treatment of, 266
— nitrification of, 269
— precipitation of, 270
— purification of, 265
— removal of, 221
— Scott-Moncrieff system, 273
— septic tank system, 271
— sludge, 271, 280
— systems of removal, 221
— trenching of, 229-235
Sewerage, 258
— Shone system, 258
— — ventilation of, 263
Sewers, 249
Ships, 356
Sierra Leone, mortality in, 10
Slaughter houses, 318
Sleep, 20
Sleeplessness in Tropics, 15
Slop-water, disposal of, 240
Sludge, sewage, 271, 280
Small-pox, 346, 349
Smut, 149
Snakes, preventing access of, 313
Sodium carbonate in food, 194
Soil, 282
— dampness of, 282
— disturbance of, 291
— microbes in, 292
— obstructed drainage of, 283
— wet, injurious, 282
Soil of graveyards, 292
Soils, temperature of, 4
Solah Topee, 16
South Africa, water weirs, 55
Soy bean, 113, 116
Space, cubic, for jails, 325
— floor, for hospitals, 320
Spaces, open, 305
Spectacles, 16
Spongilla fluviatilis, 50
Springs, 32, 42
Stables, 319
Steam disinfection, 361
— sterilization of water, 90
Stegomyia fasciata, 8, 341, 349, 385
Sterilization of water by chemicals, 81
— — — by heat, 85
Sterilizers, portable, 78, 85
Stores, disinfection of, 152
Storm-water channels, 242
— removal of, 242
Streams, silting up of, 284
Street hygiene, 294
— planning, 305, 307
Streets, height of houses in, 305
Streptothrix actinomyces, 163
Subterranean water, 26, 31
Sulphur fumigation, 363, 364
Sulphuric acid disinfectant, 363
Sun, exposure to, 15
Supplies, water, 48
Surface waters, 48
— — purity of, 52
Suspended matter in water, 68
Swine fever, 162

Tænia cœnurus, 172
— *echinococcus*, 172
— *marginata*, 172
— *mediocanellata*, 164
— *saginata*, 167
— *solium*, 170
Tanks as water supplies, 60, 62
— filling up, 247
— sterilization of water of, 81
— water, 30
Tapeworms, 164
Tea, value of, for drinking, 71
Temperature, body, in Tropics, 12
— hottest, 2
— surface, 3
Terai hat, 16
Texas fever, 162
Thatched roofs, 314
Thresh's disinfector, 362
Tick fever, 162, 386
Tiles for damp course, 313

Tilletia caries, 149
Tonne Vidangeuse Pneumatiques, 229
Towers for latrines, 250
Town planning, 303, 307
Towns, prevention of malaria in, 369, 371
Toxins due to proteid diet, 132
— of *aspergillus*, 147
Transport of water, 64
Trenches, area of, 230
— filling in, 231
— for excreta, 201
— — jails, 334
— kinds of, 230
Trenching, Allahabad system, 233
— combination with septic tank, 236
— grounds, 229
— — cocoanut plantations for, 235
— — cultivation of, 232
— — flies and, 234
Tribolium, 150
Trichina, 172
Tropics, 1, 2
— food-requirements in, 136
— illnesses of, 14
Trypanosomiasis, preventive measures against, 383
Tube-wells, 39
Tuberculosis of cattle, 163
— and insanitary areas, 301
Tylenchus tritici, 151
Typhoid bacillus, isolation from water, 101
— fever, preventive measures against, 380
— swine, 162

Upland waters, 48
Uredo fœtida, 149
Ustilago segetum, 150
Utensils of hospitals, 322
Utricularia in water, 50

Vaccination, cholera, 346, 350
— plague, 347, 348, 351
— small-pox, 346, 349
— typhoid, 351, 380
Vegetable-feeders, excreta of, 196
— juices, purification of water by, 71
Vegetables, 114
— and Chinese gardener, 238
— dangers of, 177
Vegetation, influence on climate, 7
— near houses, 293
Vetches and lathyrism, 147
Vibrio tritici, 151
Villages, prevention of malaria in, 369

Walls of houses, 311
Warm bath, 18
Washington-Lyons' disinfector, 361
Water, ablution, 196
— algæ in, 49
— carriage of sewage, 248
— closets, 251
— conduits for, 55
— deep-seated, 26
— detection of contamination of, 45
— diseases caused by impure, 67
— distilled, 24
— examination of, 100
— filtration of, 60, 90-99
— from peat districts, 54
— — tanks, 60, 62
— gathering grounds, 54
— ground, 26, 35, 50
— isolation of disease germs from, 100
— lake, 48
— leeches in, 69
— ova in, 69
— purification of, 70-79
— rain, 26
— — amount of, 243
— rivers as sources of, 57, 59
— search for, 24
— slop, disposal of, 240
— sources of, 26
— spring, 32
— sterilization of, 75, 81, 85, 90
— storm, removal of, 242
— subterranean, 26, 31
— surface, 48
— — purity of, 52
— suspended matter in, 68
— transport of, 64
— pipes, 66
— supply, 23, 48

Water supply, Mauritius, 73
— — of gaols, 329
— — of Melbourne, 53
— — without drainage, 286
— tanks, 30
— ways, keeping clear, 284
— weirs for, 55
Waterhouse-Forbes sterilizer, 86
Waters, upland, 48
Weevil, 150
Weir, leaping, 28
Weirs for water, 55
Wells, artesian, 44
— classification of, 34
— contamination of, 34, 39
— deep, 34, 42
— protection of, 35, 41
— shallow, 34
— — dangers of, 37
Wells, sterilization of, 80
— tube, 39
Werner-Schmidt process, 187
West Africa, mortality in, 10
— Indies, mortality in, 9
Willson's method for isolation of *B. typhosus*, 101
Workshops of jails, 326
Worm, bladder, 164
— tape, 164
— trematode, 174

Yam, 114
Yellow fever, preventive measures against, 354, 385

Zone, sub-tropical, 2
— torrid, 1
Zones of climate, 2